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An overview of biofuel as a renewable energy source: development and challenges

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Abstract

Depletion of petroleum derived fuel and environmental concern has promoted to look over the biofuel as an alternative fuel sources. But a complete substitution of petroleum derived fuels by biofuel is impossible from the production capacity and engine compatibility point of view. Yet, marginal replacement of diesel by biofuel can prolong the depletion of petroleum resources and abate the radical climate change caused by automotive pollutants. Energy security and climate change are the two major driving forces for worldwide biofuel development which also have the potential to stimulate the agro-industry. Nonetheless, there are other problems associated with biofuel usage such as automotive engine compatibility in long term operation and also food security issues that stem from biofuel production from food-grade oil-seeds. Moreover, severe corrosion, carbon deposition and wearing of engine parts of the fuel supply system components are also caused by biodiesel. Discussing all this advantages and disadvantages of biodiesel, it is comprehended that, a dedicated biodiesel engine is the ultimate solution for commercializing biodiesel. Brazil successfully boosted their bioethanol marketing by introducing flexible-fuel vehicles (FFV), which have a dedicated engine for both ethanol and gasoline. A similar approach can bring a breakthrough in biofuel commercialization and production. So dedicated biofuel engine is a challenge for mass commercialization and utilization of biofuel. In this lecture worldwide biofuel scenario is assessed by biofuel policies and standards. Different biofuel processing techniques are also summarized. Some guidelines on dedicated biofuel engine are prescribed. Minor modifications on the engine may not cost much; but continuous research and development is still needed.

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Keywords: Biofuel; diesel engine; emission;

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1. Introduction

Fossil fuels are widely used as transportation and machinery energy source due to its high heating power, availability and quality combustion characteristics, but its reserve is depleting day by day. The diesel engine was invented by Dr. Rudolph Diesel and it was run by peanut oil at the Paris Exposition in the year 1900 [1]. So it has been established from then that, high temperature of diesel engine is able to run on variety of vegetable oils [2]. Today diesel-powered vehicles represents about one-third of the vehicles sold in Europe and the United States and it is being predicted that the sales of diesel run automotives will rise from 4% in 2004 to 11% by 2012. As an alternative for petro diesel in the transportation sector, biodiesel can easily become the crucial solution for environmental problems. First, it does not require any engine

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modifications; second it reduces greenhouse gas (GHG) emission substantially and finally it also improves lubricity. These factors has make biodiesel usage more adaptable and attractive to current energy scenario, which are to ensure energy security, environmental sustainability and also to boost rural development by shifting of power from petro to agro-industry, simultaneously.

However, the use of raw vegetable oils as fuel may give rise to a variety engine problem, such as coking of injectors on piston and head of engine, carbon deposits on piston and head of engine and also excessive engine wear [3-5]. In order to overcome these problems, many researchers had recommended the use of transesterified vegetable oils that can greatly reduce the viscosity of the oil and this transesterified vegetable oil is termed as biodiesel. Biodiesel (Greek, bio, life + diesel from Rudolf Diesel) refers to a diesel-equivalent, a processed fuel derived from a biological source.

Biodiesel is the common name for a variety of ester-based oxygenated fuels [6] from renewable biological sources. It can be made from processed organic oils and fats. In technical terms, biodiesel is a diesel engine fuel comprised of monoalkyl esters of long-chain fatty acids that is derived from vegetable oils or animal fats [7-10]. It is designated as B100 and must meet the ASTM D 6751 requirements [11] and transesterification is an esterification process of long chained triglycerides of vegetable oils into fatty acid methyl esters (FAME) which is coined as biodiesel. To date, many vegetable oils have been used to produce biodiesel namely Peanut, Rapeseed, Safflower, Sunflower, Soya bean, Palm, Coconut, Corn, Cottonseed and Linseed. There were also biodiesel produced from non-edible oils such as Mahua, Neem, Karanja and Jatropha, which become hype in the light of recent food versus fuel conflict [11, 12]. But this debate lost its ground as most of the government policies permits only 5-20% biodiesel blend (B5- B20) with petro diesel. In the last decade, biodiesel has been proved to be technically sound when blended in low percentage either of by field trials or by laboratory experiments.

1.1. Biofuel feedstocks and utilization

The two most commonly use biofuel types are biodiesel and bioethanol which were derived mainly from vegetable oils, seeds and lignocelluloses. Biodiesel can be use to substitute diesel and bioethanol can be use in terms of petrol. Common biodiesel feedstock comes from plant oils like rapeseed, soybean, sunflower, palm and some other non-edible oils like Mahua, Neem, Karanja, Jatropha, Animal fats like beef tallow and used cooking oil can also be used as biodiesel after refining, while new sources like algae is considered to be the third generation of biofuel (source: Wikipedia). Biodiesel contains no petroleum, but it can be blended at any proportion with No. 2 diesel fuel to be used in diesel engines with little or no modification. Fuel grade biodiesels are produced through the transesterification process conforming to strict specifications such as ASTM D6751 in order to ensure proper performance and quality. On the other hand, bioethanol is made mostly from the fermentation of sugarcane, corn, wheat, maize and potatoes. Brazil has been successfully reduced their dependency on petrol by introducing fuel-flex vehicle which are modified for the use of bioethanol and also bioethanol-petrol blends.

1.2. Biofuel development

1.2.1. Asia

Currently, Asia’s largest biofuels producers are Indonesia, Malaysia, Philippines, Thailand, People’s Republic of China and India [13]. In other words, Southeast Asian countries along with two economic giants, i.e. India and China are the only participants in the biofuel industry. While, Southeast Asian countries mainly focus on export, India and China are putting forth their biofuel programs to keep up with their bullish economic growth and to reduce petroleum dependency.

Malaysia: Malaysia and Indonesia are respectively the largest and second largest producer of palm oil in the world [14], jointly, they produces about 85 % of world’s palm oil. Palm biodiesel production in Southeast Asia (SE Asia) is drastically rising due to its high potential and yield factor. The tropical climate suitable for palm growth and also the relative cheap labour of this region have made palm biodiesel production more appealing [15]. Malaysia’s biodiesel production is mainly palm oil based; however, some initiative has been taken to introduce Jatropha for mass production. Palm oil is derived from the flesh of the fruit of the oil palm tree *Elaeis Guineensis*. Palm tree was originated from West Africa (more specifically Guinea Coast). It has been initially introduced in Malaysia as an ornamental plant in 1870’s and in Thailand just before World War II. The first commercial plantation in Malaysia and Thailand has only started in 1960’s [16]. Malaysia produces 0.5 million tons of waste cooking oil every year and a simple purification and conversion process of used palm and coconut cooking oil can easily recycled the waste into good quality biodiesel. But in January 2009, palm diesel production has

accelerated in Malaysia with Indonesia as raw palm oil price gone down 75% with respect to January 2008 [17].
Indonesia: According to Indonesia's Ministry of Energy and Mineral Resources, 520,000 tons of biodiesel were produced in 2007 which was equivalent to 590,000 kL. Indonesia has projected to achieve 2.41 million kL by 2010 and the country has already achieved 24.4% of its objective so far. To date, there are currently eight biodiesel plants and by 2011, there will be another 15 - 17 more, adding some 2 million kL to the total biodiesel production [13].
Thailand: Thailand has progressed well after setting a target in January 2005 to replace 10% of diesel by biodiesel by the year 2012. There were about 800 gas stations selling B5 blends in 2007. The steady progresses of Thailand and Indonesia in this sector were mainly due to the availability of different types of feedstock. Thailand's main biodiesel feedstock is palm but it also uses coconut, Jatropha and used cooking oil. For bioethanol production, the feedstock was mainly from molasses, cassava and sugarcane. On the other hand, Indonesian produces bioethanol from sugarcane and cassava. Conversely, the biofuel production in Malaysia was generally focused on palm biodiesel, this has make Malaysia more susceptible to the fluctuation of petroleum and palm oil (food grade) prices. This is mainly due to the versatility of palm oil usage, ranging from food product to biodiesel; thus, making it the most sought after vegetable oil in the world.
India: According to the International Energy Agency's report "World Energy Outlook 2007", the worldwide energy demand would be 50 % higher in 2030 than that of today. China and India alone were accounted for 45 % of the increase in demand in this scenario. Meanwhile, India's major source of energy is coal which is used for electricity generation and currently, petroleum is imported to cope with the growing demand for transport fuel. For India, its ethanol market is more mature than its biodiesel market. In 2003, the Ministry of Petroleum and Natural Gas has launched the first phase of the Ethanol Blended Petrol (EBP) Program that mandated the blending of 5% ethanol in gasoline for nine states (out of a total of 29) and four union territories (out of a total of 6) [18]. As India does not have any surplus on edible vegetable oil, their biodiesel production was mainly focused on non-edible vegetable oil such as Jatropha, Mahua, Karanja and Neem.
The National Mission on Biodiesel was launched in April 2003 and has identified Jatropha as the most suitable oil seed plant with aim of reaching the targeted 20 % (B20) by year 2012. To achieve this, the Government has targeted 11.2 million hector areas to be planted with Jatropha by 2012 to produce sufficient oil seeds to support the biodiesel requirements. The first two phases of demonstration projects were implemented [19].
Peoples Republic of China (PRC): Currently, 80% of (the) PRC's fuel grade ethanol was made from corn, while the rest was from wheat. Cassava and sweet Sorghum are used on experimental basis only. (The) PRC only uses the inferior corn for ethanol production to avoid using its food stock. All fuel grade ethanol production and selling is controlled by state owned companies. There are currently six (6) possible biofuel feedstock, i.e. corn-derived ethanol; cassava-derived ethanol; sweet sorghum-derived ethanol; soybean-derived biodiesel; Jatropha fruit-derived biodiesel; and used cooking oil-derived biodiesel [19]. (The) PRC is one of the world's largest importers of edible vegetable oils. The majority of biodiesel plants are small scale and do not operate all the time probably due to the lack of feedstock. It may be the result of the Government not providing incentives for the production of biodiesels [16]. Chinese biodiesel production is minimal compared with its ethanol production. According to USDA, their biodiesel production amounted to approximately 300,000 metric tons. Almost all production was based on animal fat or waste vegetable oils.

Table 1. A short summary of worldwide official biofuel targets [12, 20, 21]

Country	Official Biofuel Targets
Brazil	40% rise in ethanol production, 2005-2010; Mandatory blend of 20–25 % anhydrous ethanol with petrol; minimum blending of 3 % biodiesel to diesel by July 2008 and 5 % (B5) by end of 2010
Canada	5% renewable content in petrol by 2010 and 2 % renewable content in diesel fuel by 2012
European Union	10% in 2020 (biofuels); target set by European Commission in January, 2008
UK	5% by 2020 (biofuels, by energy content)

2. Worldwide biofuel policies and standards

In this section, a thorough view on biofuel policies, targets and its standardization (especially on biodiesels) of **Malaysia:** The "National Biofuel Policy" was introduced by the Ministry of Plantation Industries and Commodities of Malaysia on 21 March, 2006. It has five strategic thrusts:

i. Biofuel for transport,
ii. Biofuel for industry,
iii. Biofuel technologies,
iv. Biofuel for export and
v. Biofuel for a cleaner environment.

However, the Envo Diesel (5% Palm Methyl Ester and 95 % Diesel) project has been aborted by Malaysian government as it has failed to market it in 2008 as planned in "The National Biofuel Policy" [21].

Indonesia: The Government of Indonesia established its first national policy on biofuels in 2006 by setting a target of replacing 10 % of transport fuel by biofuel by 2010. The national oil company Pertamina has started selling the B5 biodiesel blends commercially but has suffered serious financial losses due to the high feedstock price of biofuel. In order to compensate the losses, the blend ration was lowered to 1% now. This phenomena have plunged the Indonesian government to the target to 2.5% diesel excision by biodiesel and 3% gasoline by ethanol in 2010 [4].

Table 2. Biofuels policies in selected Asian countries [2, 11, 22]

Country	Targets for 1st-generation biofuels and plans for 2nd-generation biofuels	Blending mandate	Economic measures
(the) PRC	Take non-grain path to biofuel development	Ethanol: trial period of 10% blending mandates in some regions	Ethanol: incentives, subsidies and tax exemption for production Diesel: tax exemption for biodiesel from animal fat or vegetable oil
India	No target identified Promotion of Jatropha	Ethanol: blending 5% in gasoline in designated states in 2008, to increase to 20% by 2017	Ethanol: excise duty concession Ethanol and diesel: set minimum support prices for purchase by marketing companies
Indonesia	Domestic biofuel utilization: 2% of energy mix by 2010, 3% by 2015, and 5% by 2025 Seriously considering Jatropha and cassava	Diesel: blending is not mandatory but there is a plan to increase biodiesel blend to 10% in 2010	Diesel: subsidies (at the same level as fossil fuels)
Japan	Plan to replace 500 ML/year of transportation petrol with liquid biofuels by 2010. Promotion of biomass-based transport fuels	No blending mandate upper limits for blending are 3% for ethanol and 5% for biodiesel	Ethanol: subsidies for production and tax exemptions
Malaysia	No target identified Promotion of Jatropha, nipa, etc.	Diesel: blending of 5% palm oil in diesel	Diesel: plans to subsidize prices for blended diesel
Philippines	No target identified Studies and pilot projects for Jatropha	Ethanol: 5% by 2008; 10% by 2010 Diesel: 1% coconut blend; 2% by 2009	Ethanol and diesel: tax exemptions and priority in financing
Thailand	Plan to replace 20% of vehicle fuel consumption with biofuels and natural gas by 2012 Utilization of cassava	Ethanol: 10–20% by 2008 (Gasohol 95) Diesel: 5% (B5) mix in 2007 and 10% (B10) by 2011	Ethanol: price incentives through tax exemptions

Peoples Republic of China: The government of China is making E10 blends mandatory in five provinces that accounted for 16% of the nation's passenger cars.

India: The Indian government through its bioethanol program has called for E5 blends throughout most of the country and is targeting to raise this requirement to E10 and subsequently to E20. A 5 % target of bioethanol incorporation into transportation fuel was set by the sugar ethanol program. However, there were no direct financial assistance or tax incentives provided for the production or marketing of ethanol or ethanol blended petrol. On contrarily, financial support was provided for research and development in ethanol production that was undertaken by the public and private organizations.

3. Characterization of biodiesel:

Quality standards for producing, marketing and storing of biofuel are being developed and implemented around the world in order to maintain the end product quality and also to ensure consumers' confidence. The US and EU standards are the most referred standards followed by standards from other biofuel producing nations. Basically, the majority of the standards have similar limits for most of the parameters (i.e. sulfated ash, free glycerol content, copper strip corrosion, acid number, etc.); however, different definition for the term biofuel occurred. For instance, both fatty acid methyl esters (FAME) and fatty acid ethyl esters (FAEE) were accepted as biodiesel in the Brazilian and US biodiesel standards, whereas according to the current European biodiesel standard only fatty acid methyl esters (FAME) is applicable. A comparison of biodiesel standards was shown in Table 3 and a short discussion on key fuel properties of biodiesel and their standards in the EU and US standards were outlined below:

Flash point: Flash point is a measure of flammability of fuels and thus an important safety criterion for transport and storage. The flash point of diesels is half of that of biodiesel fuels and therefore it represents an important safety asset for biodiesel. The flash point of pure biodiesels is considerably higher than the prescribed limits, but can decrease rapidly with increasing amount of residual alcohol [5, 23].

Viscosity: The kinematic viscosity of biodiesel is higher than that of fossil diesel, and in some cases, at low temperatures biodiesel can becomes very viscous or even solidified. High viscosity can affect the volume flow and injection spray characteristics in the engine. At low temperature it may even compromise the mechanical integrity of the injection pump drive systems [24].

Sulphated Ash: Ash content is defined as the amount of inorganic contaminants such as abrasive solids and catalyst residues and the concentration of soluble metal soaps contained in the fuel. These compounds are oxidized during the combustion process to form ashes that were responsible for engine deposits and filter plugging [23].

Cloud Point: The behaviour of automotive diesel fuel at low ambient temperatures is an important quality criterion, as partial or full solidification of the fuel may cause blockage of the fuel lines and filters, leading to fuel starvation, problems of starting, driving and engine damage due to inadequate lubrication. The melting point of biodiesel products depends on chain length and the degree of saturation, where long chain of saturated fatty acid esters displaying unfavourable cold temperature behaviour [24].

Copper strip corrosion: This parameter describes the tendency of a fuel to cause corrosion to copper, zinc and bronze parts of the engine and storage tank. A copper strip is heated to 50°C in a fuel bath for three hours, followed by comparison with a standard strips to determine the degree of corrosion. Corrosion resulting from biodiesel might be induced by some sulphur compounds or by acids; hence this parameter is correlated with acid number [12].

Cetane number: The cetane number of a fuel describes its propensity to combust under certain conditions of pressure and temperature. High cetane number is associated with rapid engine start and smooth combustion. On the other hand, low cetane number causes deterioration in combustion behaviour and higher exhaust gas emission of hydrocarbons and particulate. In general, biodiesel has a slightly higher cetane numbers than fossil diesel. Cetane number increases with increasing length of fatty acid chain and ester groups, and is inversely related to the number of double bonds [12].

Water content and sediment: The Brazilian and American standards combine both water and sediment content into a single parameter, whereas the European standard treats water as a separate parameter with sediment as Total Contamination. Water is introduced into biodiesel during the final washing step in the production process and has to be reduced by drying. However, even if very low water content was achieved after production, it does not guarantee that a biodiesel fuels will still meet the specifications during combustion because biodiesel is very hygroscopic and it can absorb water in a concentration of up to 1000 ppm during storage. Once the solubility limit is exceeded (at about 1500 ppm of water in fuels containing 0.2 % of methanol), water will start to separate from the fuel and begin to deposits at the bottom layer of the storage tank [23]. Free water promotes biological growth, forming sludge and slime that in turn may cause blockage of fuel filters and fuel lines. Moreover, high water contents are also associated with hydrolysis reaction that is responsible for converting biodiesel to free fatty acids which is also linked to fuel filter blockage. It also promotes the corrosion of chromium and zinc parts within the engine and injection systems [12].

Carbon residue: Carbon residue is defined as the amount of carbonaceous matter left after evaporation and pyrolysis of a fuel sample under specific conditions. Although this residue is not solely composed of carbon, the term “carbon residue” is found in all three standards because it has long been commonly used. The parameter serves as a measure for the tendency of a fuel sample to produce deposits on injector tips and inside the combustion chamber when used as automotive fuel [12].

Acid number: Acid number or neutralization number is a measure of free fatty acids contained in a fresh fuel sample and of free fatty acids and acids from degradation in aged samples. If mineral acids are used in the production process, their presence as acids in the finished fuels is also measured with the acid number. It is expressed as mg KOH required for neutralizing 1 gm of FAME. Higher acid content can cause severe corrosion in fuel supply system of an engine.

Free glycerine: The content of free glycerol in fatty acid methyl ester (biodiesel) is dependent on the production process, and high values may be resulted from insufficient separation during washing of the ester product. Glycerol may also separate during storage once its solvent methanol has evaporated. Free glycerol will separate from the biodiesel and falls to the bottom of the storage or vehicle fuel tank, attracting other polar components such as water, monoglycerides and soaps. These components can lodge in the vehicle fuel filter and cause damage to the vehicle fuel injection system [25]. High free glycerol levels can also cause injector coking.

Total Glycerol: Total glycerol is the sum of the concentrations of free glycerol and glycerol bound in the form of mono-, di- and triglycerides. Its concentration depends on the production process. Fuels that do not meet these specifications are prone to coking; thus, may cause the formation of deposits on the injector nozzles, pistons and valves [26].

Phosphorus: Phosphorus in FAME stems from phospholipids (animal and vegetable material) and inorganic salts (used frying oil) contained in the feedstock. Phosphorus has a strong negative impact on the long term activity of exhaust emission catalytic systems.

Distillation temperature: This parameter is an important tool, like ester content, for determining the presence of other substance and in some cases meeting the legal definition of biodiesel (i.e. monoalkyl esters).

Oxidation stability: Given to their chemical composition, biodiesel fuels are more susceptible to oxidative degradation than fossil diesel fuel. This is especially true for fuels with high content of di -and higher unsaturated esters because the methylene groups adjacent to the double bonds are particularly susceptible to radical attack as in

4. Biodiesel processing technology

Biomass processing technologies have a long history of development. All biomass conversion technologies can be subdivided in two major categories - thermo-chemical conversion and biochemical conversion. Pyrolysis, gasification and liquefaction are the common thermo-chemical process to produce syn-oil, bio-syngas and bio-chemicals respectively, from biomass. On the other hand, biochemical conversion process produces bioethanol and biodiesel. Bioethanol is produced by either fermentation or hydrolysis from different sources such as sugarcane, maize, potatoes, wheat, etc. Biodiesel is produced by the transesterification process, which is actually an alcoholysis process that converts triglycerides of vegetable oil to fatty acid methyl/ ethyl esters by displacing alcohol from an ester by another alcohol [28]. Bioethanol is fungible to petrol which is used in spark ignition engine. Similarly, biodiesel is interchangeably for diesel which is widely used in compression ignition engines.

Transesterification of triglycerides are first conducted by E. Duffy and J. Patrick in 1853. Famous German inventor Rudolph Diesel invented the diesel engine in 1893 when his paper entitled ‘The theory and construction of a rational heat engine’ was published in the same year [13]. Modifications and continuous improvements had been carried out by several researchers on the transesterification process to obtained higher yield rate of biodiesel and generally, for commercial transesterification process, the catalytic method is widely used.

Table 3. Physicochemical properties of biodiesel and biodiesel standards around the world [4, 11]

Properties (units)	**Malaysia**	**Indonesia**	**Thailand**	**USA**	**EU**	**Brazil**
		Indonesian National Standardization Agency	**E 14214**	**ASTM D6751**	**E 14214**	**ANP 42**
Flash point (°C)	182 min.	100 min.	120 min.	130 min.	120 min.	100 min.
Viscosity at 40°C (cSt)	4.415	2.3- 6.0	3.5- 5	1.9- 6	3.5- 5	-
Sulphated Ash (% mass)	0.01 max.	max. 0.02	max. 0.02	0.02 max.	0.02 max.	0.02 max.
Sulphur (% mass)	0.001 min.	0.001 min.	0.001 min.	0.001 min.	0.001 min.	-
Cloud point (°C)	15.2	Max. 18	-	-	-	-
Copper corrosion (3hr, 50°C)	Class 1	Class 3	1	Class 3	Class 1	Class 1
Cetane number	-	51 min.	51 min.	47 min.	51 min.	-
Water content and sediment (vol.%)	0.05 max.	0.05 max.	-	0.05 max.	-	0.05 max.
CCR 100% (% mass)	-	-	Max. 0.3	0.05 max.	-	0.1 max.
Neutralization value (mg, KOH/gm)	-	-	-	0.05	0.05	0.08
Free glycerin (% mass)	max. 0.01	max. 0.02	max. 0.02	max. 0.02	max. 0.02	max. 0.02
Total glycerin (% mass)	max.0.01	max. 0.24	max. 0.25	max. 0.24	max. 0.25	0.38
Phosphorus (% mass)	-	max.10 ppm(mg/kg)	max. 0.001	max. 0.001	max. 0.001	-
Distillation temperature	-	<360°C	-	< 360°C	-	<360°C
Oxidation stability, hrs	-	-	6	3	6	6

For catalytic transesterification method, the catalyst used can be either homogeneous or heterogeneous. Homogeneous catalyst are mainly alkaline (e.g. sodium hydroxide, sodium methoxide and potassium hydroxide) [29] or, acidic (e.g. sulfuric acid, hydrochloric acid and sulfonic acid) [30] in nature. Enzymes, titanium silicates, alkaline earth metal compounds, anion exchange resins and guanidine heterogenized on organic polymers are some of the heterogeneous type of catalysts used for transesterification [31]. Different types of transesterification approaches are shown in Fig. 1.

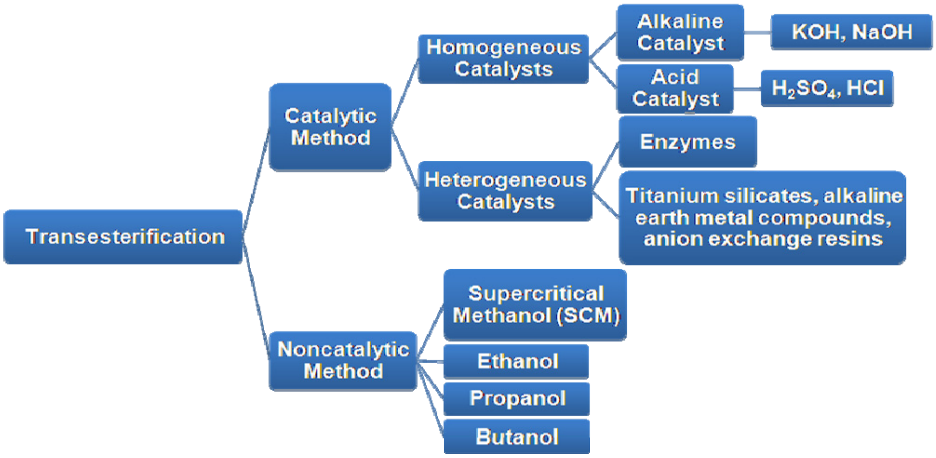

Fig. 1. Classification of Transesterification Processes

4.1. Catalytic method

For catalytic transesterification method, the catalyst is first dissolved into the methanol by vigorous stirring in a small reactor. Then, the oil that is to be transesterified will be transferred into a biodiesel reactor, followed by the catalyst/alcohol mixture. The final mixture is stirred vigorously for 2 hour at 340 K in ambient pressure. A successful transesterification reaction will produce two liquid phase: ester and crude glycerine. The crude glycerine, the heavier of the two liquid, will collect at the bottom after several hours of settling. Phase separation can be observed within 10 min and can be completed within 2 hour of settling; however, sometimes complete settling can take as long as 20 h. After the settling process is completed, water is added at a rate of 5.5% by volume of the methyl ester of oil followed by stirring for 5 min, before the glycerine is allowed to settle again. The washing step is a two-step process, which must be carried out with extreme care. A wash solution that comprised of 28 % water by volume of oil and 1 g of tannic acid per liter of water is added to the ester followed by gentle agitation. Air is carefully introduced into the aqueous layer while simultaneously stirring very gently. This process is repeated until the ester layer becomes clear. After settling step, the aqueous solution is drained, and only water is added at 28 % by volume of oil for the final washing step. An outline of the catalytic transesterification process is shown in Fig. 2.

Transesterification or alcoholysis is the usual conversion process used to convert triglycerides of vegetable oil to fatty acid methyl esters (FAME) by displacing alcohol from an ester by another alcohol [28]. For each triglyceride three monohydric alcohols reacts to produce (m) ethyl ester and glycerine (Fig. 3). An excess of alcohol is used to move this reaction towards the production side and catalysts are used to increase the reaction rate and yield of esters. Among the different type of catalysts used (i.e. alkali, acid and enzyme based), alkali based catalysts are most widely used in industrial processes because it is more effective [32] and less corrosive to the industrial equipment [33].

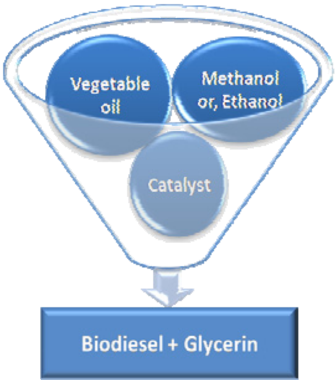

Fig. 2. Catalytic Transesterification

4.2. Non-catalytic method

The Transesterification of triglycerides by supercritical methanol (SCM), ethanol, propanol and butanol has proved to be the most promising process because of its higher yield of biodiesel obtained in a shorter period. The non-catalytic biodiesel production using supercritical methanol consists of a simple process and its higher yield production is due to the simultaneous Transesterification of triglycerides and methyl esterification of fatty acids [34]. The reaction mechanism of vegetable oil in SCM was proposed based on the mechanism developed by Krammer and Vogel [35] for the hydrolysis of esters in sub/supercritical water. The basic idea of supercritical treatment is based on the effect of the relationship between pressure and temperature upon the thermo physical properties of the solvent, such as dielectric constant, viscosity, specific weight and polarity [36]. Supercritical transesterification is carried out in a high-pressure reactor (autoclave).

The autoclave is heated by an external heater for about 15 minutes. The temperature of the reaction vessel can be measured by an iron-constantan thermocouple and maintained at approximate 5 K for 30 minutes. The transesterification reaction occurs during this period. At the end of each run, gas is vented out and the transesterified product is transferred into a collecting vessel. All the contents are emptied out from the autoclave by washing with methanol.

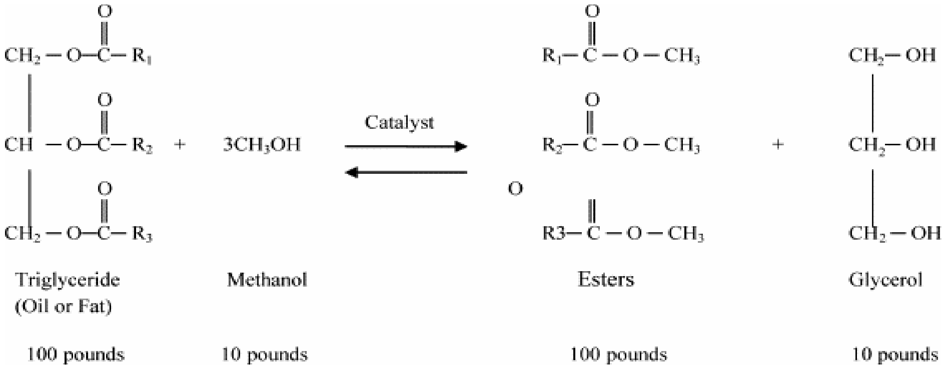

Fig. 3. Stoichiometric transesterification reactions

4.3 Factors affecting transesterification process

Several aspects such as the type of catalyst used, the molar ratio of alcohol to vegetable oil, temperature, water content and free fatty acid content have significant influence on the production rate and the quality of the produced biodiesel.

5. Advantages and Disadvantages of Biodiesel

Biodiesel have some advantages and disadvantages [2, 5, 11] which are listed as follows:

5.1. Advantages of biodiesel:

1. Portability, availability and renewability of biodiesel.
2. Biodiesel emits fewer emissions such as CO_2, CO, SO_2, PM and HC compared to diesel.
3. Producing biodiesel is easier than diesel and is less time consuming
4. Biodiesel can make the vehicle perform better as it has a Cetane number of over 100. Moreover, it prolongs engine life and reduces the need for maintenance (biodiesel has better lubricating qualities than fossil diesel).
5. Owing to the clarity and the purity of biodiesel, it can be used without adding additional lubricant unlike diesel engine.
6. Biodiesel hold a great potential for stimulating sustainable rural development and a solution for energy security issue.
7. Biodiesel does not need to be drilled, transported, or refined like diesel.
8. Biodiesel is more cost efficient then diesel because it is produced locally.
9. Biodiesel is better than diesel fuel in terms of sulfur content, flash point, aromatic content and biodegradability.
10. It is safer to handle, being less toxic, more biodegradable, and having a higher flash point.
11. Non-flammable and non-toxic, reduces tailpipe emissions, visible smoke and noxious fumes and odors
12. No required engine modification up to B20.
13. Higher combustion efficiency

5.2. Disadvantages of biodiesel:

1. It emits Higher NOx emission than diesel.
2. Higher pour and cloud point fuel freezing in cold weather causing a cold weather starting.
3. Biodiesel has a corrosive nature against copper and brass.

4. The high viscosity (about 11–17 times greater than diesel fuel) due to the large molecular mass and chemical structure of vegetable oils leads to problems in pumping, combustion and atomization in the injector systems of a diesel engine.
5. Biodiesel lower engine speed and power. The biodiesels on the average decrease power by 5% compared to that of diesel at rated load
6. degradation of biodiesel under storage for prolonged periods
7. Coking of injectors on piston and head of engine.
8. The high viscosity, in long term operation introduces the development of gumming, formation of injector deposits, plugging of filters, lines and injectors, ring sticking as well as incompatibility with conventional lubricating oils.
9. Carbon deposits on piston and head of engine.
10. Biodiesel causes excessive engine wear
11. Biodiesel is not cost-competitive with gasoline or diesel.

5. 3. Environment and establishment

Palm oil is one of the most rapidly expanding crops in the world and it is posing a threat to the biodiversity of the Southeast Asian rain forests due to its huge environmental impact triggered by the growing market demand and higher yield factor [37, 38]. Problem started when, to increase palm oil production to keep up with the international demands become a national policy; hence, rainforest has been clear out to make way for palm plantation either by logging or burning. Moreover, wastage from palm mills creates huge water pollutions that negatively impacted the aquatic biodiversity. Other potential pollutants include palm oil mill effluents (POME), fertilizers, insecticides, rodenticides and herbicides [4]. The Malaysian government has recently announced that it will ban the conversion of 'protected forests' and 'forest reserves' to oil palm plantations and will only allow areas zoned for agriculture to be developed. Policy development and implementation should not only focus on higher production rate but must also take into account the conservation of forest and environment as well. Many researchers have claimed in GHG saving by biofuel, but very few have actually done a complete analysis of the total life cycle of biofuel from farm to 'burn'. Therefore, a comprehensive comparative factors analysis of life cycle of both petroleum based fuel and biofuel is vital to draw a bottom line about GHG saving or not. A more detailed life cycle based on GHG emission for both petroleum based fuel and biofuel is shown in Fig. 4.

Unfortunately, most of the papers stated some percentage of GHG savings without mentioning what are the factors they have considered other than a clear comparison of petro diesel vs. Biodiesel engine emission only. Generally, about 40-80 % reduction of engine emissions are reported by most papers using biofuel, but very few discussed what their assessments is

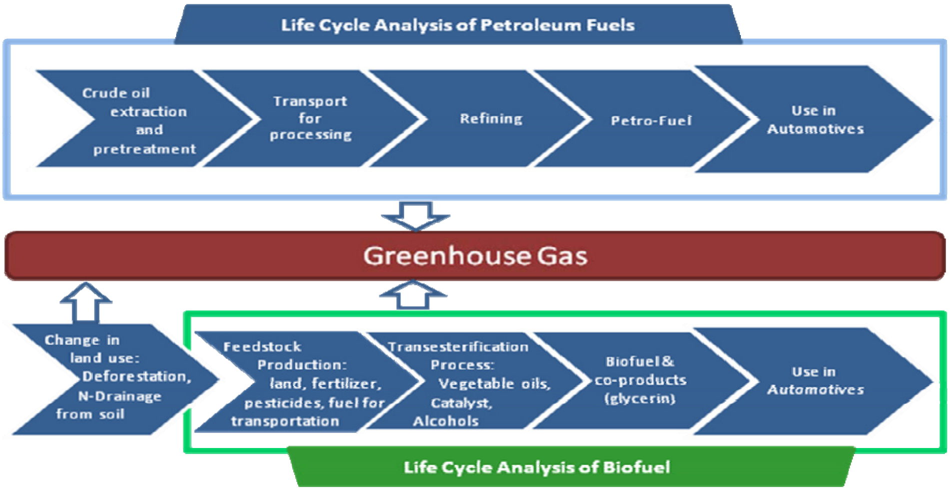

Fig. 4. Life cycle analysis of greenhouse gas balances of biofuel and petro-fuel

based on. There was an attempt to measure GHG emission for using palm oil in electricity production in comparison to coal based electricity production where a 50 % reduction has been reported.

5. 4. Major engine problems of using biodiesel

In an effort to determine long term effect of biodiesel on engine, researcher have addressed following fuel properties of fatty acid methyl esters which required to be tailored properly for engine compatibility.

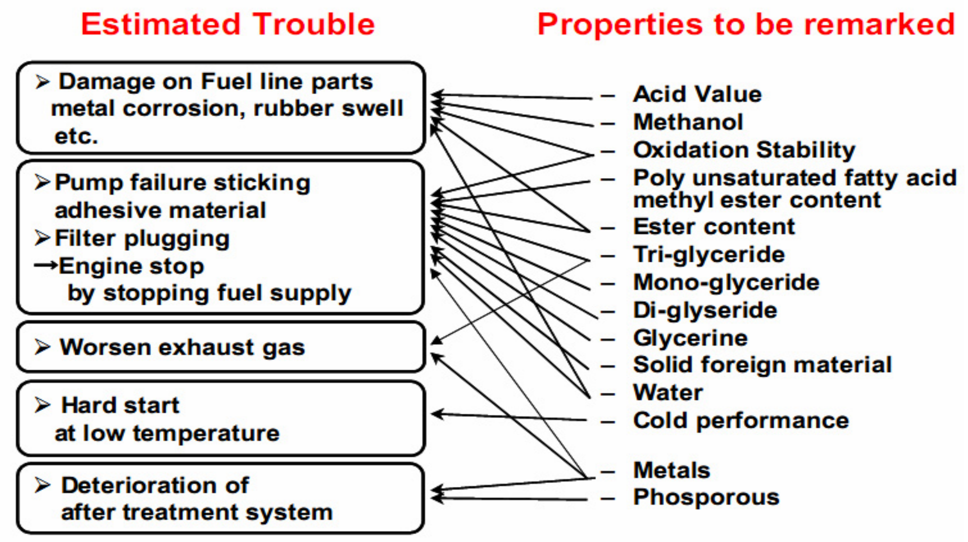

Fig. 5. FAME Properties to be remarked and the Estimated Impacts

6. A comprehensive solution-biofuel engine

Biofuel have many advantages as well as disadvantages; however, for marketing it, it requires certification from the engine manufacturers as adaptable fuel. But many engine fouling and complain caused by biofuel which are not possible to completely sort out without engine medication.

Brazil successfully utilized it vast agricultural resources and has uses bioethanol in highest proportion in their flexible-fuel vehicle (FFV) or dual-fuel vehicle. Bioethanol, being highly corrosive and hygroscopic can caused a lot of engine problems, thus to overcome this problem, the FFV uses a different fuel system that can adapt with bioethanol (E85). Moreover, the Flex-fuel engines are capable of burning any proportion of the resulting blend in the combustion chamber as its fuel injection and spark timing are automatically adjusted according to the actual blend detected by an electronic sensors. Biodiesel may have to overcome many challenges to become a feasible substitute for conventional petro diesel and by far, it has been commercialized by the government and has enjoyed high subsidies. The main hurdle in penetrating the market is the high production cost of biodiesel relative to petroleum where major factor affecting biodiesels price is its feedstock price [39]. In order to reduce cost, the transesterification process needs to be economical and high yielding. On the agricultural aspect, low manpower cost, tropical environment and high yielding oilseed crops are important factors for vegetable oil based biodiesel. From this biodiesel industry, smallholder farmers will be benefitted by generating employment and increasing rural incomes, but the scope of those benefits is likely to remain limited with current technologies [40]. Technological advancement through continuous research and development is another challenge. A modified biodiesel engine is the only solution to compensate engine compatibly problems caused by the high viscosity and high cetane number of biodiesel. The fuel supply system also requires modification especially in the fuel filter and fuel pump. Adjustment of injection timing is also needed as biodiesel have a higher cetane number where the injection timing should be retarded a little. Even though biodiesel has lower energy content where the engine may loses some power, but it can runs quieter and the fuel burns cooler, thus reducing NO_x emissions. Fuel Injection Equipment (FIE) Manufacturers (Delphi, Stanadyne, Denso, Bosch) showed their concern on following fuel properties of biodiesel**:**

- Free methanol: Corrosion of fuel injection equipment
- Dissolved and free water: It causes reversion of biodiesel to fatty acid and finally results to filter plugging
- Free glycerin: Free glycerin corrodes non-ferrous metals, soaks cellulose filters, Sediments on moving parts and Lacquering which causes filter clogging, injector Coking.
- Mono and di-glycerides
- Free fatty acids: Provides an electrolyte and hastens the corrosion of zinc, salts of organic acids, Organic compounds formed. Final result is corrosion of fuel injection equipment, Filter plugging, sediments on parts.
- Total solid impurity levels
- Alkaline metal compounds in solution
- Oxidation and thermal stability

Fuel Pump also suffers badly while operating in biodiesel blends. A list of fuel pump problems is given below:

- Corrosion of fuel injection equipment components
- Elastomeric seal failures
- Low pressure fuel system blockage
- Fuel injector spray hole blockage
- Increased dilution and polymerization of engine sump oil
- Pump seizures due to high fuel viscosity at low temperatures
- Increased injection pressure

Even though various research approaches on troubleshooting the problems of biodiesel is being carried out, a definite solution for all of this may not be possible without a dedicated biodiesel engine. For example, the Brazil's flex-fuel vehicle that has a modified diesel engine that can use different biodiesel blends (i.e. B5 to B20). It is quite achievable by modifying the fuel supply system (fuel pump, filter, injector, fuel tank, fuel lines and injection controller). Project on dedicated biodiesel engine as such may spur the biodiesel production and usage along with a hike in automobile sales like Brazil, who produced 17 million FFV automobiles by 2009.

Some suggestions on modifications of a diesel engine to a dedicated biodiesel automotive engine are listed below [41]:

1. **Fuel Pump:** Pump material (like aluminum alloy, iron based alloy) should be changed to a more corrosion resistant material. To reduce the seizure of the pump, a heating system can be run by radiator's heat.
2. **Fuel Filter:** As prescribed by many automobile manufacturer and researchers, engine requires more frequent change of fuel filter while running on biodiesel. But this will incurs extra cost to user and also require regular inspection as well. So a reinforced fuel filter container (to prevent the crash of highly viscous biodiesel) and a smaller meshed fuel filter can provide a good solution to this problem (Fig. 6).

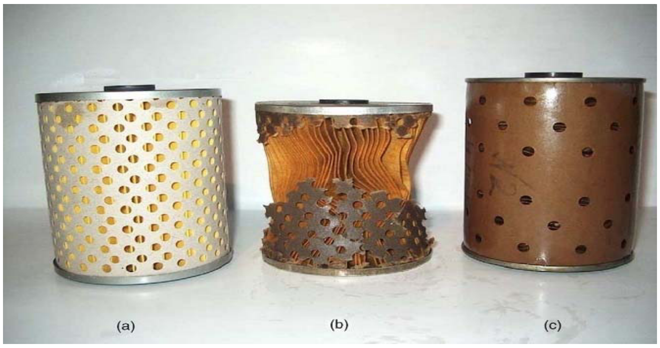

Fig. 6. The external view of a new fine porous filter element (a) that was damaged during experiments by pure rapeseed oil (b) in comparison with reinforced fielem (c) suitable to withstand oil pressure

3. **Fuel Injectors:** Jones et al. [42] have recommended that fuel injectors checking should be at least twice as often for biofuel user than that of diesel because of their coking and rapid ageing. Carbon deposition on the tip of injector is obvious, if the fuel used contains biodiesel even in minor proportions.
4. To avoid plugging and coke formation, the temperature of the nozzle has to be measured and kept (acting on the cooling water flow rate) below250 ◦C [43]. Such a nozzle design is proposed by Sgroi *et al.* [43], as shown in Fig.7.

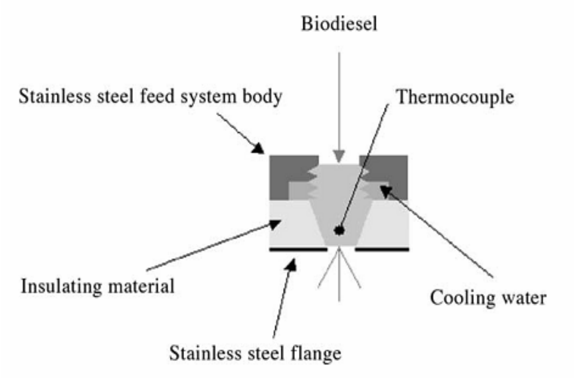

Fig. 7. Sgroi et al. proposed injector for biodiesel operation

7. Research on biofuel in university of Malaya

University of Malaya has many academicians who are working on the research and development of the upcoming alternative fuel-biodiesel. For instance, the Department of Mechanical Engineering, the Department of Chemical Engineering and the Institute of Biological Science from the Faculty of Science are all currently working on different aspect of biofuel research.

7.1. Department of Mechanical Engineering

Department of mechanical engineering have a group of researchers devoted in continuous research and development of biofuels of various sources like palm, coconut, Jatropha, ethanol etc. Prof. Dr. Masjuki Hj. Hassan, Dr. Md. Abul Kalam and Prof. Dr. A.S.M.A. Haseeb have all been working on this alternative energy field for over ten years now. The research facilities and expertise of the Mechanical Engineering Department are in the engine tribology aspect (i.e. corrosion, wear and lubrication), various regulated (i.e. CO, HC, PM, NO_x, CO_2) and unregulated (i.e. PAH) engine emission, engine performance, endurance test, fuel deposition characterization and fuel and lube oil additives effectiveness measurement. A medium scale biodiesel plant was also installed to initiate the department's new research approach on biodiesel production processes.

7.2. Department of Chemical Engineering

Prof. Dr. Mohamed Kheireddine Aroua (Production/Process), Associate Prof. Ir. Dr. Abdul Aziz Abdul Raman (Production/Process), Prof. Dr. Nik Meriam Nik Sulaiman (Production/Process), Dr. Farouq Sabri Mjalli (Production/Process) and Prof. Dr. Mohd Ali Hashim (Process) has all contributed significantly to the research and development (R&D) of biofuel. The research facilities and expertise of the Department of Chemical Engineering pertaining to biodiesel lies in the processing technology, the separation process of transesterification, the use of different bio-catalyst, biodiesel production and also key fuel properties estimation-formulation-measurement for different feedstock and blends.
Associate Prof. Ir. Dr. Abdul Aziz Bin Abdul Raman

- Selective Purification of Biodiesel Using Inorganic Membrane, Principal Investigator (PI), 2009-2009.
- Production of Palm Biodiesel from RBD Palm Oil Using Continuous Membrane Reactor, Supervisor, 2008-2009, MOSTI.

- Production of palm biodiesel from RBD palm oil using continuous membrane reactor, Principal Investigator (PI), 2007-2009, MOSTI.

Prof. Dr. Nik Meriam Binti Nik Sulaiman

- Factors affecting the clouding of palm olein, Masters' Student Supervisor, 1998-1998, IPPP
- Conceptual study on life cycle assessment (LCA) of palm oil, PhD Supervisor, 2001-2001, PORIM Research Grant
- Life Cycle Studies (especially related to palm oil industries), PhD Supervisor, 2001-2005, Geran MPOB
- Experimental evaluation of tropical biomass burning emissions, Principal Investigator (PI), 2001-2005, IRPA.

7.3. Institute of Biological Science, Faculty of Science

Academicians from the Institute of Biological Science has been using a wide range of sources to produce biodiesel, ranging from waste vegetable oil to algae. Wastes from palm oil, corn oil, sunflower oil, soybean oil, canola, rice bran oil have been successfully converted into biodiesel after several treatments followed by the transesterification process. Beef tallow, chicken and fish by products are also used as feedstock for their new projects. The most recent project on biodiesel would be from algae where they have successfully produced a small amount of biodiesel from two local species.

8. Conclusions

Current trends in energy consumption are neither secure nor sustainable- environmentally, economically or socially. A forthcoming energy crisis will seize our social and economic growth if we do not change our usual practice and selection of energy source. Severe shortage of petroleum fuels is projected as inevitable in near future coupled with a drastic environmental implication. Hence, the hunt for an alternative clean fuel is vital. To date, wind, solar, tidal and fusion energy are all very prospective type of renewable energy. However, for a growing demand of transport fuel for millions of existing automobiles, we need an alternative that can easily adapt with the present supply and storing system and biofuel is such a candidate. Due to the fact that it is fungible to petrol and diesel in internal combustion engines with little modification.

Research has shown that internal combustion engines designed for petroleum fuels usage, which not suitable for long time operation on biofuel. Hence, a little modification can give a comprehensive solution in tailoring fuel properties for engine compatibility. And, Brazil has been the most successful nation in utilizing bioethanol with the introduction of its Flexi-fuel vehicles. On the contrary, to date, there is no modified vehicle patent that runs on biodiesel. Considering all the pros and cons and fuel properties this can be comprehended that multi-functional fuel additives may make biodiesels more engine compatible, but it will increases its price. So a mass production along with utilization needs a dedicated engine which could be done by modifying present day diesel engines on fuel supply system only.

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