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Contents

Biofuel

Biofuel

Biofuels are fuels derived from biomass or organic matters such as plants and animals. With natural mechanism called “photosynthesis”, plants capture sunlight and transform solar energy into chemical energy.

Plants are a form of bio-energy because they are originated by this natural mechanism. When humans and animals eat plants as food, they will obtain the organic substances useful to their bodies. Hence, the term “biomass” refers to organic resources derived from those living things which are undergone a suitable process to transform into usable energy.

The difference between biofuels and fossil fuels (coal and petroleum) is that biofuels are renewable on the other hand quickly replace themselves and are usually available in a never-ending supply as long as trees and plants can be replenished through cultivation while fossil fuels are non-renewable with ending-supply, once they are used up, they cannot be immediately replaced within human time.

The different states of biofuel such as solid, liquid, and gas, is advantageously applicable to multi-purposes. Above all, biofuel combustion does not produce additional amount of carbon dioxide while giving off toxic gas in less amount than other typical fuels when compared per unit. Thus, biofuel utilization is to help reduce emission to the environment as a whole.

Nowadays, only 15% of biofuel utilization is globally used. For this reason, several research works to optimize the use of biofuels are encouraged, particularly in developed countries in Europe where biofuels are used for electricity generation in small power plants and in agricultural sector.

Three Major States of Biofuel

1 *Solid state*

Biofuels are in the form of wood, sawdust, rice straw, corncobs, dried sugarcane stems, manure, charcoal, horns, agricultural residues such as rice husks, cotton, peanuts, etc. Firewood is the first type of bio-energy that humans have been using to cook food and to provide domestic heating for thousand years. Wood is significantly composed of 50% of cellulose and other several chemical compounds which produce variable heating values. Wood with low humidity provides more heating value than that with high humidity as it can be seen fresh firewood produces low heating value. However, wood resources are now diminishing substantially along with wood cutting worldwide.

2 *Liquid State*

Bio-energy in liquid state falls into three major categories as follows:

- **Alcohol** is organic compound in volatile liquid state. There are two types of alcohol used for fuel produce: ethanol (edible alcohol) and methanol (inedible alcohol)
- **Vegetable oils and animal fats** such as refined vegetable oils, used cooking oil, animal fats, and biodiesel derived from vegetable oils, animal fats, and used cooking oils which are undergone chemical process.
- **Refused oils** are oils with identical chemical and physical properties to those of petroleum and can be extracted from biomass for application.

3 *Biogas (Gaseous State)*

Biogas typically refers to methane produced by the fermentation of organic matter like manure in an oxygen-free environment. It is used as fuel energy for household and business applications as well as for electricity generation. The process is common in rural areas because it provides a convenient way of turning waste into electricity. The use of biogas is encouraged because methane burns with a clean flame and produces little pollution. 1 cubic meter of biogas produces 21.5 MJ of heating value or an equivalent of 0.46 kg. of heating value of liquefied petroleum gas (LPG) or 1.2 kWh of electricity and 1.6 kg. of charcoal.

Apart from methane, there is hydrogen which can be produced from other production processes such as cracking, the process whereby complex organic molecules are converted to simpler molecules; and electrolysis, the process of breaking a chemical compound down into its elements by passing a direct current through it.

Thailand can produce fuel energy only a small portion of national fuel consumption which is not self-sufficient, while national fuel consumption is continuously increasing along with the economic growth. For this reason, it is necessary to put a high priority on the research and development for renewable energy in order to reduce the national dependency on fossil fuels. Presently, various types of biofuels commercially produced and sold in Thailand are ethanol, gasohol, (purified) palm diesel and biodiesel.

Ethanol

C_2H_5OH

Ethanol

Ethanol or Ethyl Alcohol is an alcohol with the chemical formula C_2H_5OH .That is the product of the fermentation of starch and sugar. It is a colorless, highly flammable and high octane liquid (99.8% anhydrous ethanol contains octane number = 113). Ethanol finds diverse applications such as alcohol beverages, a solvent in industrial products, a gasoline octane enhancer known as gasohol and it is also used in food industry.

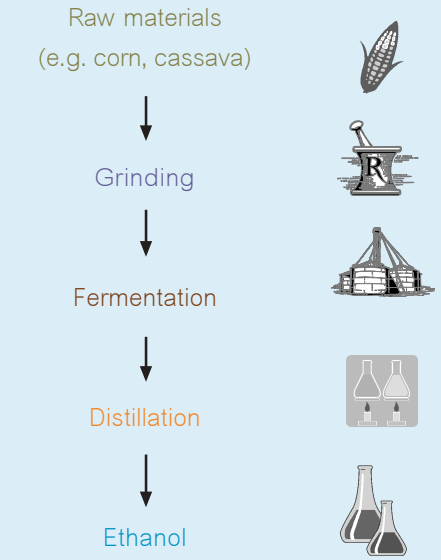
Ethanol can be produced by both the chemical process to synthesize ethanol with ethylene as the raw material, of which the end product is called "synthetic ethanol"; and the widely-used biochemical process involving with domestic agricultural products containing starch or sugar as the raw materials such as corn, sorghum, cassava, sugarcane, molasses, seaweed, of which the end product is called "bio-ethanol". Besides, there is an effort to develop the ethanol production technology by using the raw materials with high cellulose such as rice straw, sawdust and grasses.

Ethanol Production Process

There are two major processes for ethanol production from agricultural crops, which are fermentation and distillation. In order to produce ethanol from starchy raw material like cassava, the starch must first be converted into sugar by using acids or enzymes so that the raw material is in a proper condition before entering the fermentation process.

Fermentation refers to the process using yeast to convert sugar into alcohol or ethanol, while distillation is the process that fermented ethanol is distilled under the atmospheric pressure. The ethanol obtained will be purified to 95.6% by volume. For ethanol used as fuel, "dehydration techniques" must be used to enable hydrous ethanol (95.6% by volume) to become absolute ethanol or anhydrous ethanol (99.5% by volume).

Ethanol Production Process



Ethanol Utilization

- Directly replacing gasoline and diesel fuels, the method that engine parts must be specially designed to provide anti-corrosion because ethanol is a mild acid.
- Blending ethanol with gasoline (yielding gasohol) or diesel (yielding diesohol) at a ratio varied to each country applications, for instance, blending with gasoline at a ratio of 10% by volume is called “gasohol”, at a ratio of 85% is called “E 85” and so on.
- As an additive or octane enhancer, replacing MTBE (methyl tertiary butyl ether) or ETBE (ethyl tertiary butyl ether) which are petroleum products.

As a clean fuel, ethanol can achieve greater environmental benefits. E 10 or 10% ethanol reduces the emissions of certain pollutants from engine exhausts as well as provides more complete combustion than diesel and gasoline do.

However, using ethanol as a fuel in automobiles is successful in the countries with sufficient supply of agricultural starchy crops. For example, Brazil uses ethanol produced from sugarcane, and U.S.A. produces ethanol from corns. Presently, the experi-ments on ethanol used as an aviation fuel are also conducted.

Gasohol

Octane 95

Gasohol

Gasohol is a gasoline alternative fuel consisting of a blend of 91 Ron unleaded gasoline and 99.5% pure ethyl ethanol by volume at a ratio of 9 : 1 or 90% gasoline and 10% ethanol by volume.

Gasohol Production Process

(Gasoline)

+

(Ethanol)

Gasohol

(GAS(OLINE) + (ALC)OHOL)

Properties of Gasohol

Most gasohol sold in Thailand has octane number of 95 (orange color) with chemical and physical properties as specified by the Department of Energy Business, Ministry of Energy, which can be used in any types of automobile without engine modifications as recommended by automobile manufacturers. Normally, it is applicable to an automobile with electric fuel injection system.

Gasohol specifications are as follows:

1. Octane number is not less than 95.0 representing anti-knock ability or enhancing more complete combustion.

2. Vapor pressure at the temperature of 37.8°c is less than 62 kilopascal (kPa), indicating the vaporization ability of the fuel supply system of engine to ease starting.

3. As a fuel, gasohol quality resembles gasoline 95. MTBE as an octane enhancer is normally specified to be blended with unleaded gasoline 95, while ethanol is used likewise in gasohol blending.

* A car can be filled up with gasohol fuel regardless the fuel type left in the gas tank without engine modification since gasohol fuel will not harm the engine and help in a complete combustion.

Benefits of Gasohol Usage

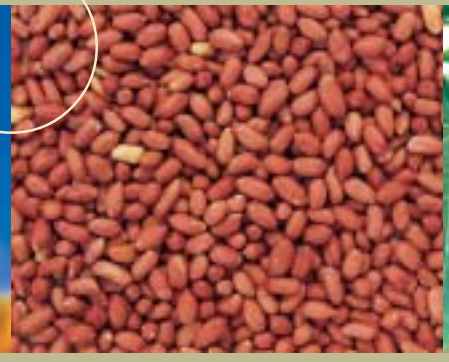
For engines

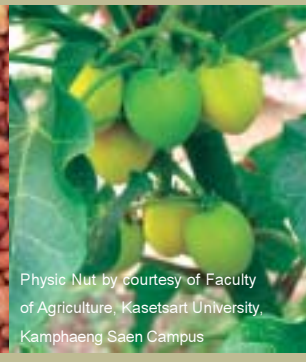
- More complete combustion comparable to gasoline 95
- No major effects on driving performance and provides better acceleration
- No expenses on engine modifications
- Can be filled up in the fuel tank to mix with gasoline.

For the Country

- Oil import and trade imbalance reduction
- Optimum use of domestic crops and crop prices raised
- Less air pollution with the reduction of carbon dioxide by 20-25% resulting in the public health enhancement
- Investment promotions in agricultural and industrial sectors

Vegetable Oil





Physic Nut by courtesy of Faculty of Agriculture, Kasetsart University, Kamphaeng Saen Campus

Vegetable Oil

Vegetable oil is processed oil derived from plant sources such as peanuts, soybeans, sunflower seeds, safflower, oil palm, coconut, castor beans, physic nuts, rapeseeds, etc. In general, vegetable oil is a triglyceride compound with high viscosity and molecular structure C_3H_5, connecting a variety of fatty acids, accounting for 94-96% of molecular weight of triglyceride.

Vegetable oil used as a fuel

Vegetable oil and diesel have the common properties. Therefore, it is more suitable to run vegetable oil on diesel engines than on gasoline ones, particularly low-speed diesel engines such as agricultural and fishery engines.

Each type of vegetable oil gives off varying heating value, which is roughly 83-85% of diesel by weight and is 10 times more viscous than diesel. It is more difficult for the fuel injector to spray vegetable oil, posing yet another problem in feeding of fuel into the combustion chamber and resulting in incomplete combustion. Since vegetable oil vaporizes slowly and in small quantities, ignition is difficult and unvaporized carbons could deposit on fuel injector, cylinders, rings and valves when run on high-speed engines. In addition, vegetable oil is unstable, as the temperature falls, the viscosity increases until it forms a waxy-like substance creating an obstacle to fuel supply system.

Properties and Heating Values of Vegetable Oil Varieties Compared with Diesel Fuel

Variety of Oil	Specific Gravity$^{(at21^{\circ}c)}$ (gm/ml.)	Viscosity$^{(at\ 21^{\circ}c)}$ (Centipoise)	Heating Value (kilo joules/kg)
Soybean Oil	0.918	57.2	39,350
Sunflower Oil	0.918	60.0	39,490
Coconut Oil	0.915	51.9	37,540
Peanut Oil	0.914	67.1	39,470
Palm Oil	0.898	88.6	39,550
Palm Kernel Oil	0.904	66.3	39,720
Physic Nut Oil	0.915	36.9 $^{(at\ 38^{\circ}c)}$	39,000
Diesel	0.845	3.8	46,800

Source: Peesamai Jenvanitpanjakul, Biodiesel: Alternative Fuels V.Science and Technology 16th Year Vol.3 September-December, 2001

through the two methods as follows:

Engine modification It is quite costly to modify certain engine components such as injection system, cylinders and combustion chamber to be suitable for using with vegetable oil. Some older engines may need rubber seal changes.

Quality improvement of vegetable oil It is simpler and costs less to improve the quality of vegetable oil, for instance, to decrease viscosity and to increase volatility of vegetable oil resembling diesel in order to provide flow of fuel feeding into combustion chamber contributing to complete combustion, which makes no impact on engines in long term. The method can be done through :

- To refine vegetable oil to remove gums, fats, odors and colors
- To mix vegetable oil with diesel or other types of fuel, for example, mixing coconut oil with kerosene- the folk wisdom method-which is called “coconut diesel” and “palm diesel” when palm oil is mixed with diesel.
- To have vegetable oil undergone the chemical process to form ester resembling the chemical and physical properties of diesel while containing higher flash points and cetane number.

Compared with diesel, vegetable oil is safer and releases less pollutants, hence, it is environmentally-friendly. However, its prices vary to types of raw material used and other related factors including the sufficient plantations suitable for each area, for example, EU uses rapeseeds and sunflower seeds, soybean and coconut are used in U.S.A., and oil palm, sesame, castor, physic nut are used in Asia.

Biodiesel

B 100

Biodiesel

Biodiesel is a fuel for diesel engine chemically produced by a reaction of a vegetable oil, animal fat, or used cooking oil with an alcohol like methanol or ethanol in the presence of a catalyst to yield mono-alkyl esters and glycerin, which is removed. The process is called “Transesterification”. The mono-alkyl esters obtained has very similar properties to diesel, hence, it is called **“Biodisel” or “B100”** while the glycerin produced as a by product can also be used in pharmaceuticals, cosmetics and lubricant production.

“

Rudolf Diesel

was the first inventor of the biodiesel-powered engine which was successfully run for the first time in Germany on August 10, 1893. In remembrance of this event, August 10 has been declared “International Biodiesel Day”.

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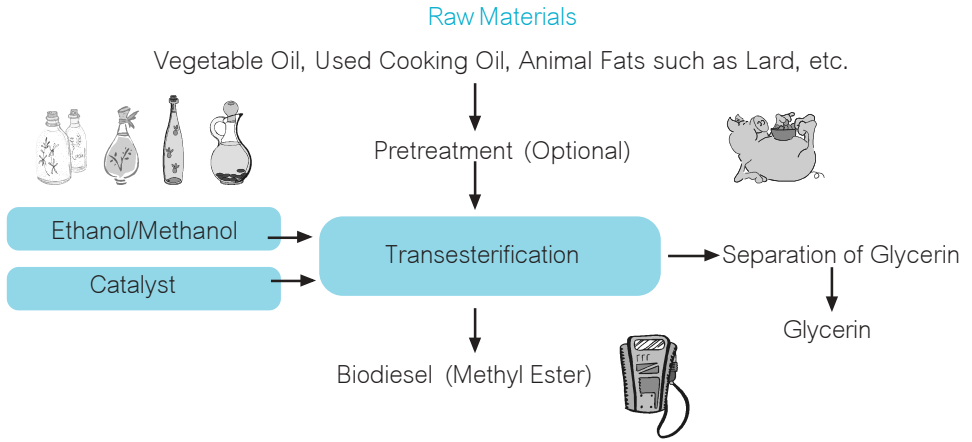
Biodiesel Production Process



Biodiesel Properties

Neat (purified) biodiesel contains higher cetane number than diesel. Above all, it is non-flammable and non-explosive with 120°c flash point whereas diesel flash point is 64°c. As a clean fuel, it enhances the efficiency of engine combustion. Biodiesel is not only compatible with low-speed diesel engines but also high-speed diesel without any application problems both in short and long terms.

When compared with diesel, biodiesel releases fewer pollutants with 20-40% of carbon monoxide, hydro carbon, and particles, as well as 60% of less black smoke.

Biodiesel Utilization

In using neat biodiesel or B100 with automobiles, some certain engine components need modifications. Blend of biodiesel not exceeding 5% (=B5) with 95% of diesel for general applications and blend of biodiesel not exceeding 20% (=B20) with 80% of diesel for car fleets, can be used without engine modifications which is accepted by automobile manufacturers.

Biodiesel has gained popularity as an alternative fuel in Europe, U.S.A., Canada, etc. due to public concerns over the world environment. Presently, Germany is the world largest user and producer of biodiesel. Biodiesel prices vary to raw material costs, production capacity, and taxes of each country.

In each country, biodiesel is applied in different proportions. B100 is widely available in Europe : Germany and Austria. B20 (20% biodiesel, 80% diesel) is available in Iowa, U.S.A. B5 (5% biodiesel, 95% diesel) is available in France. B2 (2% biodiesel, 98% diesel) is available in Minnesota, U.S.A.

Biodiesel produced and sold at a service station is required to meet the established international standards. At present, the U.S. standard for biodiesel quality is ASTM D 6751 while EN 14214 is used by EU. For Germany, DIN 51606 is required. In Thailand, biodiesel quality is required to be achieved according to the announcement of the Energy Business Department on “Specification of Fatty Acid Methyl Esters (FAME), 2005, dated July 11, 2005”

(Purified) Palm Diesel

(Purified) Palm Diesel

Thailand's first study on palm oil as a diesel fuel substitute was dated back to 1985 in accordance with His Majesty the King's initiative concerning the farmers' oversupply of palm oil as well as the impact of rising oil prices. His Majesty instructed Prince of Songkla University to build a small refined palm-oil extraction plant in Narathiwat. Consequently, the Private Affairs Division conducted the research and development work while putting palm oil on trial in diesel engine. The experiment was so successful that on April 9, 2001, His Majesty instructed Privy Councillor Amphol Senanarong to file a patent application with the Department of Intellectual Property, Ministry of Commerce, in His Majesty's name. The invention was titled "Application of Palm Olein as Diesel Fuel" with the patent number # 10764 and was later publicized on April 18, 2001 and registered on July 26, 2001.

Purified Palm Diesel sold in Thailand is diesel blended with purified palm oil at a ratio not more than 10 % by volume with fuel quality resembling high speed diesel as specified by The Energy Business Department in every aspect. A diesel-engine car can be spontaneously refilled purified palm diesel in the fuel tank regardless of an empty tank spared. In this regard, no engine modifications are required because no impacts are seen on such diesel engines, while it helps promote lubricity and anti-wear in fuel injection pump as well as cut pollutant in exhausts.

The major characteristics of purified palm diesel according to the Energy Business Department's announcement on the specifications and qualities of diesel are as follows:

- Cetane number is not lower than 47, indicating auto-ignition quality and combustion performance without engine detonation
- Viscosity value at 40°c ranging from 1.8 - 4.1 cSt (centistoke) to control fuel droplet size
- Carbon residue not higher than 0.05 by weight, carbon residue value indicates the amount of carbon residue accumulating in engine, with a large amount of it, combustion chamber deposit will occur, there may be engine component blockade that causes unsmooth engine operation.
- Lubricity performance tested by HFRR (High Frequency Reciprocating Rig) Method causing wear scar on rollers not more than 460 micrometers
- Sulfur content not higher than 0.035% by weight because fuel combustion normally produces tailpipe emission to the environment

Chemical and physical Characteristics of Diesel Fuel and (Purified) Palm Diesel Fuel

Items	Test Method	Specification of Energy Business Department	Diesel Fuel	Purified Palm Diesel Fuel
Specific gravity @ 15.6/15.6 °C	ASTM D 1298	0.81-0.87	0.8326	0.8342
Cetane index	ASTM D 976	min 47	56.6	57.2
Viscosity @ 40 °C cSt	ASTM D 445	1.8-4.1	3.137	3.725
Pour point °C	ASTM D 97	max 10	-2	-3
Sulfur content %wt	ASTM D 5453,4294	max 0.035	0.033	0.032
Copper strip corrosion (number)	ASTM D 130	max 1	1a	1a
Carbon residue %wt	ASTM D 4530	max 0.05	n.a.	< 0.001
Water and sediment %vol.	ASTM D 2709	max 0.05	< 0.005	Traces
Ash %wt	ASTM D 482	max 0.01	n.a.	0.001
Flash point °C	ASTM D 93	min 52	64.0	70
Distillation 90% recovered °C	ASTM D 86	max 357	353.5	356.2
Colour	ASTM D 1500	max 4.0	L1.0	0.5
Lubricity by HFRR μm	CEC F-06-A-96	max 460	< 460	204
Additives (In case it has been put)	Need to be approved by Energy Business Dept.			

Glossary

Biodiesel

is a diesel replacement fuel produced from vegetable oil or animal fat and used cooking oil. Through a process called “transesterification” ,organically derived oil are combined with alcohol (ethanol or methanol) and chemically altered to form fatty esters such as ethyl or methyl ester.

Biogas

is a gas produced by the fermentation of organic matter such as manure in an oxygen-free environment. Biogas primarily consists of 60-80% methane, 20-40% carbon dioxide, and other compounds like nitrogen, hydrogen, and hydrogen sulfide.

Biomass

is one of the world’s important renewable sources of energy derived from plants and animals and can be categorized according to its origin such as agricultural crops, agricultural residues, wood and wood residues, and waste streams. It can be used as a solid fuel, or converted into liquid or gaseous forms, for electric generation, heat, chemicals, or fuels.

Ethanol

or ethyl alcohol is an alcohol ,most commonly made by using a process similar to brewing beer where starch crops are converted into sugars, the sugars are fermented into ethanol, and then the ethanol is extracted into its final form by distillation.

Renewable Energy

is an energy which comes from the natural flow of sunlight, wind or water around the earth. Its energy sources are renewable or replantable such as solar energy, wind energy, hydro-energy, bio-energy, geothermal energy and so on. Via certain scientific methods, all forms of renewable energy can be produced into usable energy.

GLOSSARY

Product Comparison Table

Product	Fuel Base	Other Blend	Engine
ethanol	ethanol (ethyl alcohol)	-	gasoline
gasohol	gasoline	ethanol	gasoline
(purified) palm diesel	diesel	purified palm diesel	diesel
biodiesel	diesel	ester	diesel