COCONUT OIL AS DIESEL FUEL vs COCOBIODIESEL

By

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Abstract

Various global concerns such as the dwindling crude oil reserve, global warming and climate change, air pollution and public health, and more importantly the steady rise in the cost of fossil fuel, have altogether received rapidly growing interest in the use of renewable fuels (biofuels). For all diesel engines, alternative renewable fuels are vegetable oils referred to as bio-oils and transesterified bio-oil more popularly referred to as biodiesel. Biodiesel is a "diesel like" fuel which means it has properties very close to conventional diesel and can be used in land transport and stationary engines.

Medium speed diesel engines can operate well on the use of straight and unprocessed vegetable oil such as coconut oil. Compared to the use of biodiesel, vegetable oils will considerably reduce fuel cost in such engine.

As vegetable oils have differences in carbon chain composition, each oil must necessarily be evaluated separately. In most cases, however, vegetable oil specially coconut oil have been proven to be very clean fuels with excellent combustion properties.

Introduction

It is a fact that Rudolf Diesel invented the diesel engine in 1894 using peanut oil. This was a low-medium speed engine. The development of vegetable oil for the diesel engine did not prosper because oil companies came out with a much cheaper fuel which they called diesel fuel. In 1912, Rudolf Diesel stated *"the use of vegetable oils for engine fuels may seem insignificant today. But such oils may become in the course of time as important as petroleum and the coal tar products of the present time".* That time is now.

A couple of decades back, several studies on the use of vegetable oils as fuels in diesel engines have been carried out. In the Philippines, the "coco-diesel" program was implemented in the mid-eighties using Coconut RBD oil assigning some bus companies for the pilot program. While the performance was promising, many experienced a relatively high pour point and cloud point problems. Problems with carbon deposits in the combustion chamber were also reported. The program was discontinued thereafter.

The development of renewable fuel for diesel engines in the Philippines have hibernated until the turn of the new millennium when cocobiodiesel was introduced jointly by the Asian Institute of Petroleum Studies, Inc (AIPSI) and the oleochemical

companies (Senbel Inc. and Chemrez Inc.) to the United Coconut Planters Association (UCAP) and the Philippine Coconut Authority (PCA).

The growing global concern about environmental issues in the 90's (i.e. Clean Air Act) has increased the interest in alternative fuels paving the way to greater funding and effort for research studies. The increasing amount of greenhouse gases (ghg) such as C02 which is causing global warming and climate change, as well as the declining reserves of fossil fuels, and more importantly, the high fuel prices have strongly increased the interest in the use of bio-oils and biodiesel for land transport and power generation.

Considering that the production cost of bio-oil and biodiesel is still higher than fossil diesel fuel, its use as a "neat" diesel replacement still pose a major problem. Fuel cost is often the largest part of the operating cost of transport operators and diesel power plants which directly correlates to profitability. Governments will, however, benefit from renewable fuels in terms of displacement of fuel fuel imports.

Chemical Properties of Vegetable Oils

Vegetable oil like coconut oil consists of hydrocarbon called triglycerides. The triglyceride composition is unique for every plant oil. Triglyceride molecules consists of glycerol bound to three fatty acid molecules. Different plant oils have different compositions and there is no natural oil that consists of just one triglyceride type.

The different triglycerides have different properties and their coagulation point differ *("sebo" in Pilipino).* That is why some triglycerides coagulate before others as they are cooled.

The oxygen content is the most important difference in chemical composition between fossil oils and vegetable oils. Vegetable oils contain 10 – 12% oxygen, whereas fossil fuel normally contain insignificant amounts of oxygen. The oxygen content affects both the specific energy and combustion properties of the oils. Vegetable oils specially coconut oil do not contain any sulfur in contrast to diesel fuel. If at all, only very small traces are found. Furthermore, coconut oil does not contain any aromatic groups while mineral diesel typically contain 20-40% aromatic compounds. Another important difference is that vegetable oils are polar compounds and have high lubricity feature for "boundary" lubrication of fuel injection pumps and injector nozzle units.

Brief on Coconut Oil

For many decades, coconut known as "tree of life", has been the preferred raw material for the production of soap and cosmetics. As food, coconut oil provides many health benefits being anti-viral, anti-bacterial, anti-fungal, anti-microbial and many more. This matter is extensively discussed by Dr. Bruce Fife in his book " the Coconut Oil Miracle". Dr. Fife points at the medium carbon chain specially lauric acid (C_{12}) as the central point of its excellence. The following comparative Fatty Acid Profile of plant oils will show the significant features of coconut oil. Coconut oil as well as other plant oil consists of two (2) components – Glycerine and Fatty Acid.

Fatty Acid Profile [2] of Plant Oils (%)

	Coconut	Soybean	Rapeseed	Palm	Jatropha
Iodine Value [3]	7 – 10	117 – 141	105 – 120	44 – 54	100
Saturated Component :					
Caproic Acid (Saturated $C_{6:0}$)	0.5	-	-	-	-
Caprylic Acid (Saturated $C_{8:0}$)	8	Central point of the uniqueness of coconut oil			
Capric Acid (Saturated $C_{10:0}$)	6	-	-	-	-
Lauric Acid (Saturated $C_{12:0}$)	**47**	-	-	-	-
Myristic Acid (Saturated $C_{14:0}$)	**17.5**	0.1	1	1	-
Palmitic Acid (Saturated $C_{16:0}$)	9	11	2	**39**	15
Stearic Acid (Saturated $C_{18:0}$)	3	4	1	5	6
Arachidic Acid (Saturated $C_{20:0}$)	-	0.6	0.5	-	-
Behenic Acid (Saturated $C_{22:0}$)	-	0.3	0.5	-	-
Total Saturated Component	***91*** [5]	***16***	***5***	***45***	***21***
Unsaturated Component:					
Oleic Acid (Mono-unsaturated $C_{18:1}$)	7	**22**	**57**	**46**	**46**
Linoleic Acid (Poly-unsaturated $C_{18:2}$)	1.9	**54**	**23**	9	**33**
Linolenic Acid (Poly-unsaturated $C_{18:3}$)	0.1	8	11	-	-
Gadoleic Acid (Mono-unsaturated $C_{20:1}$)	-	-	2	-	-
Erucic Acid (Mono-unsaturated $C_{22:1}$)	-	-	2	-	-
Total Unsaturated Component [6]	***9***	***84***	***95***	***55***	***79***

Note: (2) Values taken from the Tribology Data Handbook

(3) **Iodine value** is a measure of the level of unsaturated fatty acid. Low iodine number means low in unsaturated fat. Coconut has iodine value of only 7 – 10 which means it is highly saturated.

(4) **Medium Carbon Chain** component of coconut oil. This group of carbon is also referred to as MCFA or medium carbon fatty acid in which most dominant is Lauric Acid or C_{12}. As health food, lauric acid is converted by the body into monolaurin which boosts the immune system.

(5) Level of saturated component of coconut oil (91%) which indicates oxidation stability of coconut oil.

(6) **Unsaturated** means that the carbon chain of a fatty acid is short of hydrogen making it reactive to oxidation and thus prone to bacterial growth. Mono-unsaturated has 1 carbon double bond in a carbon chain or short of 2 hydrogen. Poly-unsaturated has 2 or more double bonds or short of 4 or more hydrogen.

Coconut Oil as Diesel Fuel

The performance of vegetable oil as diesel fuel depends on the chemical composition of the plant oil particularly on the carbon chain length and the degree of saturation and unsaturation of the fatty acid molecules. Fatty acids that do not contain double bonds are referred to as saturated because they contain the maximum number of

hydrogen that a carbon molecule can hold. Fatty acids that contain 1 double bond is called mono-unsaturated or is short of 2 hydrogen, while fatty acids with 2 or more double bonds are called mono unsaturated. Unsaturated fatty acids are prone to oxidation, bacterial growth, and formation of peroxides. Between these peroxides, cross-linking can occur and can cause oil polymerization and forms a plastic-like solids (*"nata" in Pilipino*). The greater the degree of unsaturation, the greater is its oxidation characteristic, bacterial growth, and peroxidation.

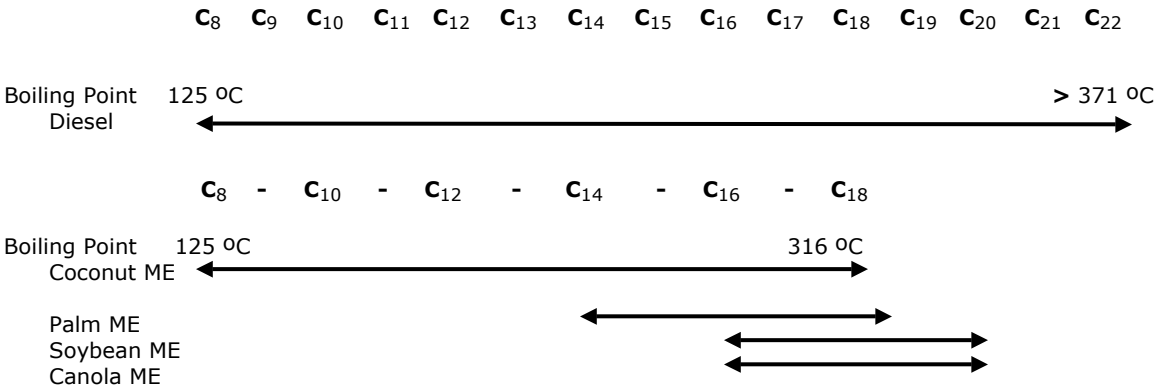
Problems related to this phenomenon can occur when vegetable oils are used as fuels for small high speed engines (such as luxury automobiles) which are more sensitive to kind of fuel and the fuel system.

Coconut Methyl Ester (or Cocobiodiesel)

In very simple term, Coconut Methyl Ester (CME) is coconut oil that has been converted to a diesel-like product. Plant oil has two main components known as glycerine and fatty acids. The fatty acid component has volatility feature similar to diesel. But in oil form, glycerine is attached to the fatty acid which causes the volatility of fatty acids to be suppressed. Glycerine has a high boiling temperature which is why plant oil makes excellent cooking oil. However, volatility is necessary for combustion when plant oil is used as fuel for internal combustion engines. It therefore necessitates the removal of glycerine.

The separation of glycerine from fatty acid is done by a reaction process known as esterification. Methanol is reacted with coconut oil with the aid of a catalyst to effect phase separation.. After a sufficient time of reaction, the methanol and glycerine are drawn out of the mixture leaving just the fatty substance known as methyl ester. Coco Methyl Ester is a diesel-like derivative of coconut oil. To a petroleum technologist, the fatty acid profile of coconut oil reveals a world of information specially when the oil is converted to various type of esters for lubrication, additive formulations, and other special applications :

First, when coconut oil is converted to a *diesel-like* product like methyl ester, its wide range of distillation from C_8 to C_{18} becomes functional. Distillation range is the range of temperatures in which liquid transforms to vapor that becomes combustible with oxygen . Over 60 % of coconut oil constitutes medium saturated carbon that will provide good front-end distillation for better combustion and cold starting performance.



Second, the high level of saturation in coconut (91%) consisting mainly of *"easy-to-burn"* saturated medium carbon chain gives two (2) excellent benefits: 1) *oxidation stability* making coco methyl ester less prone to bacterial growth (a storage issue in other biodiesels), and 2) *high cetane number* which enhances combustion and acceleration response.

Third, the medium carbon fatty acids (MCFA) of coconut specially lauric acid (C_{12}) has excellent solvency or solubility. Such feature makes CME a perfect biodiesel for developing countries like the Philippines where *old diesel engine* population comprises the majority. Old means heavy carbon deposits in combustion chamber and clogged fuel nozzles resulting in very inefficient combustion and high smoke emission. The solvency element of CME cleanses the fuel lines, decarbonizes the combustion chamber, and declogs the fuel nozzles to restore engine efficiency

Conclusion: (Maximizing the Benefit of Coconut Oil)

While the use of pure coconut oil is certainly feasible to run diesel engines specially if one is not very discriminating on its effect to engines, its use can be better maximized if it is converted to cocobiodiesel. First, the economics of cocobiodiesel in reducing fuel import is far greater when used as diesel enhancer at 1% blend than when coconut oil is used as a 1 to 1 diesel substitute. Second, Clean Air is more extensively addressed in cocobiodiesel. Third, coconut oil is currently still more expensive than diesel fuel and there usually is very small production in relation to the annual demand for diesel fuel. Take note of the following comparison using Philippine data:

1. **70 million liters of Coconut oil used as 100% diesel substitute.**

   Direct Savings on fuel import :
   70m x P30 */liter = **P 2.10 billion/yr.**

2. **70 million liters of Cocobiodiesel used as 1% diesel enhancer**

   Direct Savings on fuel import
   70m x P30 /liter = P 2.10 billion /yr.

   \+ Indirect Savings from mileage economy**
   635m x P30 / liter = P 19.0 billion /yr

   Total Savings = P 21.1 billion /yr

* Import cost of diesel fuel is P30/ liter

** Biodiesel is registered as both diesel substitute and diesel quality enhancer with inherent features for solvency, lubricity, combustion improvement, and cetane number. A 1% blend can already restore fuel system efficiency and boost diesel fuel combustion resulting in mileage improvement. Quite a number of mileage tests show conservative mileage improvement of 10% from as little as 1% blend. This translates to a 9.1% reduction in fuel consumption. If this is a national average, reduction from the annual Philippine diesel demand of 7 billion liters is 635 million liters.