

Coco-Biodiesel – A Perfect Natural Diesel

by

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(Authors are petroleum technologists and former oil company executives with more than 30 years in the Philippine petroleum industry. At the turn of the new millennium, they conducted technical studies, research, and evaluation of Coco Methyl Ester as biodiesel and played a key role in the development of the Philippine cocobiodiesel program. They are now actively promoting biofuels and introducing Ester Engineering in universities.)

Introduction

The high demand for crude oil, exacerbated by problems in crude oil supply arising from the conflicts in Iran, Iraq and Nigeria continue to cause high inflation of fuel prices in all parts of the world. The unstoppable rise in fuel prices since the onset of the new millennium with crude cost now breaching US\$75/bbl necessitates a more determined effort to *fast track development of environment-friendly alternative and indigeneous sources of energy*

The rapid increase in ethanol and biodiesel production throughout the world is a clear sign that the era of “green gold” (fuel from plant oil) has began. This time, the fertile tropical lands of Asia will be one of the major sources of such renewable fuels in the near future. Visionary companies are putting investments on ethanol and biodiesel plants in all parts of the world including Asia. Recent news indicate that even the giant Microsoft has gone out of its core business to put up a huge 750,000 tonnes biodiesel plant as well as investments in ethanol plant. On the other hand, Saudi Arabia, India, and some countries in Asia including Indonesia and the Philippines are developing experimental plantations of *Jatropha* for biodiesel with D1-Oil of South Africa providing the technology.

The advent of biofuels is a new source of economic revolution. Biodiesel from coconut is a Philippine initiative and its research and study for fuel application had been conducted by the Asian Institute of Petroleum Studies (AIPSI) at the turn of the new millennium with the support of leading coconut methyl ester manufacturers in the Philippines, Chemrez Inc. and Senbel Fine Chemicals Inc. It was initially undertaken to provide a long term, high volume, and sustainable alternative domestic market for coconut oil as well as to address the impending effectivity of the Philippine Clean Air Act. To ensure its acceptance, AIPSI funded the first laboratory test conducted at Southwest Research Institute in San Antonio, Texas, USA in 2001 and the excellent results became the foundation stone that snowballed the development of cocobiodiesel in the Philippines.

After 5 years of extensive laboratory test and analysis as well as field tests, the Philippines is now much ahead of its neighboring countries in cocobiodiesel technology. Such technology is already in our midst as Chemrez Inc. a leading biodiesel manufacturer carrying the brand “BioActiv” has completed its new biodiesel plant, a hi-tech 60,000 tonnes/yr. – the first continuous biodiesel plant in Asia.

Although the excellence of cocobiodiesel is steadily spreading nationwide and creating awareness among business and government leaders, what is not well known as yet is the fact that cocobiodiesel is the only renewable diesel fuel in the world that is closest to the profile of an ideal diesel in its natural state (i.e. no additives). Yet it is better because it contains more features than what is present in an ideal diesel. Cocobiodiesel contains two (2) main unique features not present in any other biodiesel. 1) it is 91% saturated (or just 9% short of the ideal diesel profile) giving it excellent oxidation stability. It contains high cetane number and produces low NOx emissions since these are

functions of a high level of saturation. 2) 62% of cocobiodiesel comprises medium saturated carbon chain giving it lower ignition temperature for cleaner combustion, higher solvency and detergency value for cleaning and declogging action, and better front end volatility for good cold startability. Globally, however, little is known about coco biodiesel at the present time. Hopefully, this paper can help spread the excellence of cocobiodiesel particularly in its ability to enhance the quality of all other unsaturated biodiesels.

For a petroleum technologist, cocobiodiesel is an exciting product because it is after all, a perfect natural diesel. - a hidden wealth of the coconut tree that has finally been brought to light.

Cocobiodiesel can jumpstart the “green gold” economy in Asia particularly in the Philippines (in lieu of “black gold”) as a companion to its fledging natural gas industry.

Ideal Diesel vs Commercial Diesel

In petroleum language, the ideal diesel fuel is referred to as 100% n-paraffin, a straight carbon chain structure known as “alkane”. Alkane is a saturated carbon chain. Saturated carbon means it is *not prone to oxidation and not prone to bacterial growth*. *Saturated carbon has excellent anti- corrosion properties and resistant to polymerization and gumming.* Being 100% saturated and oxidation stable in its natural state, an ideal diesel requires little or no anti-oxidant additive and has excellent combustion characteristics, has very high cetane number and produces low NOx and other undesirable emissions. It needs little enhancements only on properties that it lacks like lubricity and detergency.

However, the ideal petroleum diesel is unattainable because commercial diesel fuel produced from complex refineries today contains a blend of many components like “cracked” diesel which are of lower oxidation characteristic. Typical blend elements are olefins, iso-paraffins, aromatics, others. These components are unsaturated hydrocarbon which means the fuel is a bit more difficult to burn, is prone to oxidation, bacterial growth, corrosion, polymerization, gumming, etc. For this reason, multi-additive packages are made integral part of commercial diesel fuel formulations to address their shortcomings. Such multi-additive packages supplied by various additive companies provide the quality difference and distinction between competing brands of diesel fuel. Multi-additive packages also substantially contribute to the formulation cost of diesel fuel and a dollar drain for the country as they are also imported items.

Cocobiodiesel - A Perfect Natural Diesel

In very simple term, “biodiesel” is fuel sourced from plant oil. Coconut Methyl Ester (CME) or cocobiodiesel is coconut oil that has been converted to a diesel-like product through the removal of glycerine. Coconut oil (referred to as CNO) like all other plant oils has two main components - glycerine and fatty acids. One mole of glycerine is attached to three moles of fatty acid which is why it is also called a triglyceride. The fatty acid component has volatility features similar to petroleum diesel but while glycerine is attached to it, the volatility range is suppressed. Glycerine has a high boiling temperature and will not volatilize easily which is why vegetable oils are excellent cooking oil. However, a desirable volatility profile is necessary for combustion in high speed engines such as those used in automobiles. This therefore necessitates the removal of glycerine from the plant oil or animal fats to produce an efficient diesel fuel.

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. After a sufficient time of reaction, phase separation occurs and the methanol and glycerine are drawn out of the mixture leaving just the fatty substance known as methyl ester. Coconut methyl ester is a diesel-like derivative of coconut oil after its glycerine content has been separated. To a petroleum technologist, the fatty acid component of

coconut oil reveals a world of many possible applications specially when the oil is converted to esters for lubrication, additive products, and other special applications. The unique characteristics of coconut methyl ester and their implications to engine performance can be explained as follows:

First, the medium carbon fatty acids (MCFA) of coconut has excellent solvency or solubility. Such feature makes Cocobiodiesel a perfect biodiesel for developing countries like the Philippines where *old diesel engine* population comprises the majority. Old means heavy carbon deposits in the combustion chamber and clogged fuel nozzle tips resulting to inefficient combustion and high smoke emissions. The high solvency characteristics of coconut methyl esters, specifically its MCFA component, not normally present in other biodiesels, cleanses the fuel lines, decarbonizes the combustion chamber, and declogs the fuel nozzles to restore engine efficiency. Such restoration of fuel system efficiency accounts for the high mileage improvement on the use of Cocobiodiesel blend in diesel fuel specially in old engines.

Chart 1

	<u>Jatropha</u>	<u>Soybean</u>	<u>Rapeseed</u>	<u>Palm</u>	<u>Coconut</u>
1. SATURATED CARBON					
Medium Chain Fatty Acids (MCFA)					
Caproic (C6:0) saturated	0	0	0	0	1
Caprylic (C8:0) saturated	0	0	0	0	8
Capric (C10:0) saturated.	0	0	0	0	6
Lauric (C12:0) saturated.	0	0	0	0	47
Total MCFA	0	0	0	0	62
Long Chain Fatty Acid (LCFA)					
Myristic (C14:0) saturated	0	0	1	1	17
Palmistic (C16:0) saturated.	15	11	3	43	9
Stearic (C18:0) saturated.	8	3	2	5	3
Arachidic (C20:0) saturated.	0	1	1	0	0
Behenic (C22:0) saturated.	0	1	1	0	0
Total LCFA	23	16	8	49	29
Total Saturated Carbon	23	16	8	49	91
2. UNSATURATED CARBON					
Oleic (C18:1) mono-unsaturated. .	45	22	55	46	7
Linoleic (C18:2) poly-unsaturated. .	32	54	23	5	2
Linolenic (C18:3) poly-unsaturated. .	0	8	8	0	0
Gadoleic (C20:1) mono-unsaturated. .	0	0	3	0	0
Erucic (C22:1) mono-unsaturated. .	0	0	3	0	0
Total Unsaturated Carbon	77	84	92	51	9

Second, the high level of saturation in coconut oil (91%) consisting 62% “*easy-to-burn*” medium saturated carbon chain gives three (3) excellent inherent benefits: 1) *oxidation stability* making coconut methyl ester not prone to bacterial growth (a storage issue in other biodiesels), corrosion,

and polymerization, 2) *high cetane number* which enhances combustion and acceleration response; 3) *lower NOx emissions* for cleaner air (i.e. reduces formation of acid rain and smog)

	Saturated Carbon Chain	Unsaturated Carbon Chain	Cetane Number
Ideal Diesel (n-parrafin)	100%	0 %	> 80
Coco biodiesel	91%	9 %	70
Palm Biodiesel	49%	51 %	60
<i>Unadditized Comm'l Diesel</i>	<i>approx</i> 40%	60 %	48
Jatropha Biodiesel	22%	78 %	51
Soy Biodiesel	16%	84 %	53
Rapeseed Biodiesel	6%	94 %	61

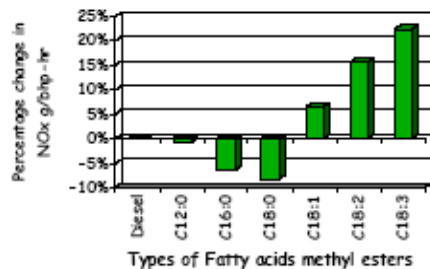
Cocobiodiesel being 91% saturated carbon consisting of 65% medium carbon chain (i.e. lower boiling point temperature) is a lot easier to combust! In petroleum language, it is 91% n-parrafin (or only 9% short of the ideal diesel profile). Being highly saturated, its cetane number is 70, and its saturation level substantially reduces NOx emission. (Note: Existing US NREL study shows NOx emission decreases when using saturated fuel and increases for unsaturated fuel. This was also seen in the study of Dr. Koji Yoshida of Nihon University when CME blend of 1-5% reduced NOx emission by 20%)



Coco Biodiesel Effect on NOx*



NOx Emissions of Biodiesel Components

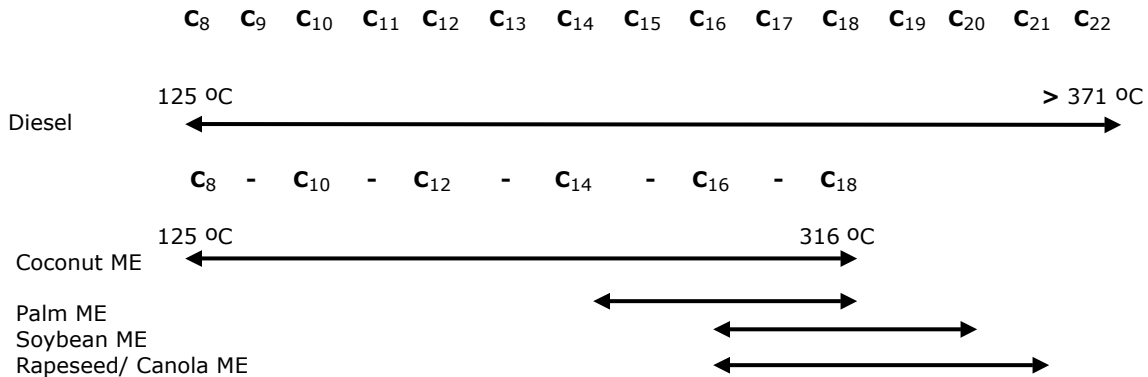


← NOx Emission increase in Unsaturated Carbon Chain

← NOx Emission decrease in Saturated Carbon Chain

Note: Cocobiodiesel is 92% saturated consisting of C8:0; C10:0; C12:0; C14:0; C16:0 and C18:0

Third, when glycerine is removed from coconut oil and the remaining fatty acid is neutralized of acidity to become a *diesel-like* product known as methyl ester, its wide range of distillation temperature becomes functional. Distillation range is the range of temperatures in which liquid volatilizes to become combustible with oxygen. The 62 % of coconut oil constitutes medium saturated carbon chain and as such, it provides good front-end volatility for better combustion and cold startability.



As shown in the foregoing charts, cocobiodiesel consists of saturated medium carbon and has wide distillation range. Most biodiesels consist of unsaturated long carbon and has narrow distillation range. This means that cocobiodiesel has better front end volatility for combustion, better cold startability, better solvency and detergency, superbly better oxidation stability, and even in small quantity add-on to diesel fuel substantially reduces NOx emissions. This makes a world of difference compared to most biodiesels which are predominantly unsaturated long carbon chain with narrow range of distillation temperature. Other biodiesels are also excellent diesel enhancers due to their oxygen and lubricity characteristics but will require oxidation-stabilizing additive because of their high level of unsaturates. Thus, cocobiodiesel is unique and a premium class of biodiesel.

Action of Cocobiodiesel in Diesel Blend

As in all biodiesels, cocobiodiesel contains oxygen in its carbon chain provided by nature to boost combustion efficiency. Additives are not needed in cocobiodiesel to improve oxidation stability because it is highly oxidation stable, neither will it require additives for lubricity because it is a lubricity enhancer by itself. It also does not need combustion improvers because it has an inherent oxygen content which serves as combustion booster, apart from its natural high cetane number which enhances acceleration response, and neither will it need detergency additive because it has natural high solvency/detergency feature.

All these features prove that cocobiodiesel is a perfect natural diesel fuel. It is closest to the profile of an ideal diesel in oxidation stability but surpasses the ideal diesel with other natural features of high lubricity, oxygen content, high cetane, and high solvency in its natural state. It is a polar compound molecule which further enhances “boundary lubrication” of moving parts in the fuel system.

Therefore, cocobiodiesel when blended with diesel fuel will further enhance the features of commercial diesel. It has two (2) main actions even from as little as 1% blend:

- 1) **Restores fuel system and engine efficiency:** Old engines with heavy carbon soot deposits and with clogged or partially clogged fuel nozzles will be cleansed and declogged in a short period of time to restore fuel spray atomization efficiency. Regular use of cocobiodiesel blend

even at only 1% will ensure cleanliness of engine. It will likewise provide film lubricant layered on metal surfaces of the fuel pump and injector unit (known as “boundary lubrication”).

- 2) **Enhances combustion efficiency:** Its oxygen content, lower distillation temperatures (rate of volatility), and high cetane number will enhance cold startability , acceleration response, and excellent power.

The foregoing actions result in efficient combustion, cleaner air, more mileage and cost savings, reduced M&R expense, prolonged engine life, and driving satisfaction.

Conclusion

There are no valid and properly founded negative technical issues that apply to CME as biodiesel being a highly saturated biodiesel. The characteristics of cocobiodiesel could even be better than an ideal diesel in its natural state as it conforms to Category 3 of the Worldwide Fuel Charter. Being a new but exciting product, it is still suffering from “birth pains” since some misinformed people are falsely attaching the negative issues attributed to unsaturated carbon on cocobiodiesel. In time, the excellence of cocobiodiesel will prevail

Developing cocobiodiesel is not just about creating an indigeneous renewable fuel as an alternative to or a blend component of diesel fuel due to the unstoppable rise in fuel prices and spiraling cost of our local petroleum import bill. It is also a ***door opener to the world of “ester engineering”*** which is virtually unknown in coconut growing countries and can be very beneficial for the Philippines in the near future.

Excellent environment-friendly products can be developed out of plant esters that have huge local and international market. For example, aviation lubricants for the past 30 years are made of C8/C10 polyol/di ester which comes mostly from coconut oil; 134-a compressor oil are made from plant oil esters; synthetic motor oils are blend of synthetic esters and poly-alpha olefins (PAO); and many more. While the Philippines currently do not have the technology knowhow to produce such specialized products, it is enough proof that coconut oil is indeed a unique and superior plant oil.

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Q & A

1. What are the diesel features * of Cocobiodiesel ?

1. Highly processed cocobiodiesel has a cetane number of 70. Cetane number is a measure of the "ignition delay" or the time gap from fuel spray to combustion. Simply stated, it is a measure of combustion efficiency of the fuel much like octane is for gasoline. The higher the number, the better is the combustion efficiency and acceleration response. Additized diesel fuel has cetane number of 51 to 55. PNS minimum standard is 48. European EN590 minimum standard is 51.
2. It has oxygen content of 11% provided by nature that enhances combustion. The oxygen content serves as combustion booster.
3. It has excellent lubricity feature. A 1% blend can already enhance the lubricity of diesel fuel by as much as 30%. It is a lubricity enhancer by itself.
4. It has a wide distillation (or volatility) range that gives good cold startability.
5. It is 91% saturated carbon and therefore burns easily. Also, 65% of its component are medium carbon chain which means they have lower ignition temperatures. It is only 9% short of the ideal diesel (100% n-paraffin) and is not prone to bacterial growth, corrosion, polymerization, gumming, others. It is the only biodiesel that is closest to the profile of an ideal diesel which is 100% saturated carbon.
6. It has a flash point of 107 °C and is about twice safer in handling and storage than commercial diesel.
7. Being 91% saturated, it has high oxidation stability in its natural state (i.e. without additive) and is equal to or better than commercial diesel that has been additized with oxidation stabilizer.
8. Its high cetane and medium carbon chain promotes clean emission substantially reducing PM by > 60%; NOx by 20%; and nearly all pollutants. Its high solvency cleanses, declogs, and restores engine efficiency making it very appropriate for developing countries where old engine population comprises the majority.
9. Having carbon- hydrogen structure similar to diesel fuel, it is a diesel component, not an additive, just as olefins and iso-paraffins are diesel components. Additives have different chemical ingredient which are mostly metal based.
10. It is biodegradable, non-toxic and contains zero or just traces of sulfur.
11. It is one of very few products or technology in the Philippines that qualifies for carbon credit trading.

2. Are there adequate tests on Cocobiodiesel ?

Laboratory tests on cocobiodiesel have been conducted in many reputable research and testing institutes all over the world. These are: The US National Renewable Energy Laboratories (USNREL), Tokyo Metropolitan Research Institute (TMRI); Daeduk Institute in So. Korea, SGS Japan; Independent Petroleum Laboratories (IPL) thru BP in New Zealand; Nihon University, BASF Germany; and many local laboratories and institutes. Furthermore, various field and engine test have been conducted under the supervision of the Philippine Dept. of Energy.

3. How does Cocobiodiesel Work?

A blend of cocobiodiesel even with a minimum of 1% will have two main actions:

- 1) It restores engine efficiency. Old engines with heavy carbon deposits and clogged fuel nozzles will be cleansed and declogged to restore fuel spray atomization efficiency. It will likewise provide film lubricant layered on metal surfaces of the fuel pump and injector unit (known as “boundary lubrication”). The high claim of mileage improvement (ranging from 10% to as high as 25%) on the use of 1% cocobiodiesel is valid only for Philippine condition and countries with similar condition. Such condition pertains to high percentage of old diesel engine population. The big mileage improvement comes from efficiency restoration through the solvency and lubricity features of cocobiodiesel.
- 2) It enhances combustion efficiency, cold startability; and acceleration response by its oxygen content, wide distillation range, high content of medium saturated carbon (i.e. easy to burn), and high cetane number.

Result of the foregoing actions are: efficient combustion, cleaner air, more mileage, lower M&R cost, prolonged engine life, and motorist driving satisfaction.

Cocobiodiesel Specification vs Standards for Biodiesel

<u>Properties</u>	<u>Coco Biodiesel</u>	<u>Philippine Std. PNS 2020:2003</u>	<u>European Std EN14214</u>	<u>US Std ASTM D6751</u>
Flash Point °C	107	100	101	130
Viscosity, cst @ 40C	2.66	2 – 4.5	3.5 – 5.0	1.9 - 6.0
Carbon Residue, %m/m	0.006	0.05	0.30	0.05
Cetane Number, min	70	42	51	47
Sulfated Ash, %m/m	nil	0.02	0.02	0.02
Water & Sediment, % v/v	0.05	0.05	0.05	0.05
Copper Strip Cor., 3h50°C	1a	3 max	1 max	1 max
Acid No., KOH/g max	0.18	0.50	0.50	0.80
Free Glycerine, Max	0.003	0.02	0.02	0.02
Total Glycerine	0.10	0.24	0.25	0.24
Distillation, T90 °C	327	360	-	360

(Note: Bold numbers surpass international standard specification)