EXPERIMENTAL STUDY OF THE BIO-ADDITIVES IN BIODIESEL FUEL ON PERFORMANCE AND EMISSIONS CHARACTERISTICS OF DIESEL ENGINE.

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ABSTRACT

Among the alternative fuels the Bio diesel is one the most common and familiar to all. It’s biodegradable, environment friendly as well as suitable source, to meet the future energy crises. The main concern of this experimental analysis is to reach a tentative goal, how this fuel can be utilised with maximum effective way. To find this ,an experiment data analysis of different parameter such as break power, break mean effective pressure consumption, emission characteristic (NOx, HC, CO, etc.), is done through bio diesel fuel and also compared with ordinary diesel which is also known as standard diesel. Despite years of improvement attempts, the key issue in using bio based fuels is oxidation stability, stoichiometric point, bio-fuel composition, antioxidants on the degradation and much oxygen with comparing to diesel gas oil. Thus, the improvement of emission exhausted from diesel engines fuelled by biodiesel is urgently required to meet the future stringent emission regulations. This investigation is carried out through 20 HP eddy current dynamometer and load cell arrangement which is controlled by a DYNAMAX® software computer in case of finding the break power and BMPE respectively. And the emission characteristics are observed using Airrex HG-540 exhaust analysers finally the result is compared with diesel engine which is run by standard diesel. Di Methyl Poly siloxane (DMPS) additive and D20 palm oil methyl formula was used in this studies. The final result implied that the bio diesel with some additives with (CP10+DMPS Power) and (JC15+ DMPS) shows best performance and reduce the exhaust emission including CO. Thus the decision may be taken, 10% - 15% blended bio diesel with DMPS additive as a best alternative fuel considering all the view aspects and alternatives.
ABSTRAK

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LIST OF SYMBOLS AND ABBREVIATIONS

ASTM - American society of Testing and Material
B10 - 10% biodiesel blend with 90% diesel content
B15 - 15% biodiesel blend with 85% diesel content
B20 - 20% biodiesel blend with 80% diesel content
B30 - 30% biodiesel blend with 70% diesel content
B5 - 5% biodiesel blend with 95% diesel content
BDF - Bio Diesel Fuel
BMEP - Brake mean effective pressure
BSFC - Brake specific fuel consumption
BTE - Brake thermal efficiency
CEN - European Committee for Standardizations
CI - Compression Ignition
CO - Carbon monoxide
CO2 - Carbon dioxide
CPO - Crude palm oil
FAME - Fatty acid methyl ester
HC - Hydro carbon
J10 - 10% Jatropha biodiesel oil blends with 90% diesel
J15 - 15% Jatropha biodiesel oil blends with 85% diesel
J5 - 5% Jatropha biodiesel oil blends with 95% diesel
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<td>POME</td>
<td>Palm Oil Methyl Ester</td>
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<td>RPM</td>
<td>Different engine speed</td>
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<td>RPM</td>
<td>Revolution per minute</td>
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CHAPTER 1

INTRODUCTION

1.1 Background of study

This study is about the effect of bio additives; Di Methyl Poly Siloxane Power (DMPS Power) and Palm Oil Methyl Ester (D20 Booster) performances and emissions in diesel engine fueled with Bio Diesel Fuel (BDF) i.e., Crude Palm oil, Jatropha Curcas oil and Waste Cooking oil. Furthermore, due to alternative fuels for diesel engine are becoming increasingly important because of diminishing petroleum reserves and the environmental consequences of exhaust gases from petroleum-fueled engines. Several developed countries have introduced policies encouraging the use of BDF made from grains, vegetable oil or biomass to replace part of their fossil fuel use in industries in order to prevent environmental degradation by using cleaner fuel and to reduce dependence on imported, finite fossil supplies by partially replacing them with renewable, domestic sources. The DMPS and D20 Bio-additives can remarkably improve the fuel economy of Compression Ignition (CI) engine while operating on all kinds of BDF. The power output of BDF depends on its, blend, quality, and load conditions under which the fuel consumed. Hence, the performance, combustion characteristics and emissions of diesel engine learnt under different speed and load conditions.

There are still debates in what the advantages and disadvantages of Bio-additives with BDF has to offer. (Fuel, Retrofits, & Neighborhood, 2005) (Wirawan, 2007) (Suffian, 2014)
1.1.1 The advantages of BDF with Bio-additives

i) Cost: The potential to cost less than fossil fuels (Will increase in importance, as price for fossil fuels will rise when the amount available lowers).

ii) Lower carbon emissions: When BDF burned, they produce less carbon output and fewer toxins.

iii) Renewability and availability: Unlike fossil fuels, BDF will not take long to be able ‘harvest’. Moreover, are renewable due to their short time needed to grow.


1.1.2 The disadvantages of BDF with Bio-additives

i) Lower output: BDF offer a lower energy output than fossil fuels, therefore need a larger amount for the same energy.

ii) Production Carbon Emissions: Where the burning of BDF create less carbon output and toxins, the production is a different thing. Due to nitrate, fertilizers and machinery necessary to cultivate the plants several studies have shown that they sometimes create equally or even more greenhouse gases than the fossil fuels.

iii) Food prices and shortages (Mostly for bio-ethanol): Food prices may rise and shortages occur due to the growing demand for BDF.

iv) Water use: Massive quantities of water used for the cultivation of these plants.

The optimal ratio of DMPS power to BDF depends on the fuel used and on the different engine operating conditions. As we know Crude Palm Oil (CPO), Waste Cooking Oil (WCO) and Jatropha Curcas Oil (JCO) have potential to use as an alternative fuel that can reduce the total emission CO₂ emissions from the internal
combustion engine. While for the DMPS power and D20 Booster used in this project claimed as environment friendly, and could increase 20% - 35% power of engine. These three different types of BDF will be mixed with DMPS power with a volume that recommended by the manufacture. The performance and emission test carried out through eddy current dynamometer and emission analyzer. It expected to investigate and analyze the combustion characteristic outcome. A Small Diesel Engine used in the experiment is YANMAR TF120ML.

Many researchers and scientists have been studying the effects of Bio-additives with BDF blends on engine performance and emissions characteristics. Most of the study reported that Bio-additives could produce lower emissions than unleaded diesel on CI engines (Khalid & Osman, 2013). Although many studies only evaluated the effect of blending ratio, researches on influences of DMPS power and BDF with combustion analysis by integrated sensors like pressure transducer in the engine performance is rarely. Hence, further report on the combustion analysis generated.

In investigation of the influences of combustion characteristic P-V diagram, cumulative pressure, heat release rate and ignition delays in CI engine, three different types of BDF (CPO, WCO and Jatropha) mixed with Standard Diesel No. 2 (STD) into different blending ratios and each mixture together with Bio-additives.

1.2 Problem Statement

The use of Bio-additives has received actively attention due to increase demand for energy and strict air pollution regulation. Researchers are actively studying and developing alternative clean fuels. Among alternative fuels, BDF with Bio-additives added is very attractive and employed most generally for CI engines to lessen carbon monoxide (CO), NOx level and total hydrocarbon emissions (HC) and to reduce the depletion of petroleum fuels simultaneously.

Nowadays the cost of domestic fuel rising become more problematic directly to consumer therefore solution in better performance of engine pressure, power and fuel consumption must be studied. According to MPOB (2012), Malaysia currently accounts for 39 % of world palm oil production and 44% of world exports. However, engine fuelled by biodiesel fuels faced the problem where the fuels are not operating
efficiently due to the variant in fuel properties. In diesel engine, the relation between mixture formation during the ignition delay period and burning process in diesel combustion that strongly affects the exhaust emissions. Thus, the improvement of emissions exhausted from engines fuelled by biodiesel is urgently required to meet the future stringent emission regulations. *(Khalid, A. et, al., 2011)*

BDF blends will require more heat to vaporize than STD. Some concerns was raised about difficulty in starting vehicles using blends at extremely low temperatures. Other concerns about low temperature fuel characteristics of blends include increased viscosity of BDF blends which may impede fuel flow and also phase separation in the vehicle fuel system due to reduced solubility (Dinesh, et. al., 2000).

Furthermore, a very rare studies about the effect of BDF with Bio-additives fuel with combustion analysis in an engine. In response to this problem, this study proposes to investigate the effect of combustion analysis and BDF-DMPS power and BDF-D20 Booster blends on compressed ignition engine.

### 1.3 Objective

The objective for this experiment are as follows:

i) Investigate the effect of Bio-additives, DMPS power and D20 Booster on performance and emissions of Diesel Engine fueled by Bio Diesel Fuel (BDF).

ii) Investigate the effect of Bio-additives, DMPS power and D20 Booster on combustion characteristic of Diesel Engine fueled by Bio Diesel Fuel (BDF).

iii) Comparative studies between Bio-additives; DMPS power and D20 Booster.

iv) Future recommendations

### 1.4 Scope of Study

The test is carried out through 20 hp eddy current dynamometer with a 0.638 liter engine and with the differences engine speed (800 rpm, 1200 rpm, and 1600 rpm to
2000 rpm). This research introduces three types of BDF with Bio-additives from three
types of BDF such as crude palm oil based (CP5, CP10 and CP15), wastes cooking oil
(WC5, WC10 and WC15) and Jatropha Curcas (JC5, JC10 and JC15) and analyzes the
effects of BDF on performance and emissions of diesel engine. The fuels will be tested
were commercial standard diesel no. 2 (STD) and blends of DMPS power with the
BDF. The ordinary gas oil with commercial standard diesel designated as a reference
standard fuel (STD). Engine used in these experiments was Yanmar Motor Diesel
Engine Model TF120-ML complete with attached sensor as below:

i) Tachometer

ii) Exhaust Temperature Sensor

iii) Dynamometer

iv) Fuel Consumption Glass Gauge

v) Combustion Transducer Sensor

vi) Eddy Current Dynamometer

vii) Emission Analyzer

Each BDF type will use at the difference blending ratio. The blended rates are 5%,
10% and 15% by volume and compared with the commercial standard diesel fuel
(STD). A 20 HP eddy current dynamometer with 0.638-liter CI engine and with the
differences engine speed (rpm) and load. Initial load in this experiment is to be
applying load from 0%, 50% and 90% with maximum rated engine speed at 2400 rpm.
Effect of DMPS power on performance, emissions and combustion characteristic of
Diesel Engine fueled by BDF then was tested.

1.5 Rationale and Significance

Based on the research scopes mentioned above, the following rationale and
significance that to be expected to get have been outlined.
i) It shall increase performance and reduce emission level of blending BDF with Bio-additives.

ii) It shall increase the production of BDFs from vegetable oils

iii) Alternative way to produce valuable product from three type of BDF (Crude palm oil, Waste Cooking Oil and Jatropha with bio-additive)

iv) New substitute of raw material for DMPS power and D20 booster production

v) It shall reduce environmental problem as Bio-additives added BDF is environmentally friendly alternative to conventional STD fuel.

Also Important of this study is to compare the performance and emission of BDF in normal condition and BDF with Bio-additives power compare to STD. Therefore, a silicone oxygenated fuel additive DMPS Power was studied in variant conditions. Another fuel additive D20 Booster also was used in comparison using CP20 blending ratio. This is important because the comparison of both Bio-additives in the BDF could provide vital information to increases its qualities and performance when used in diesel engine fleets in the future. The data that recorded during the test may be very useful for the other studies especially in Bio-additives development.

According to (Baumgarten, 2005), a stoichiometric mixture has just enough air to completely burn the available fuel. In practice this event gradually, due primarily to the very short time available in an internal combustion engine for each combustion cycle. Most of the combustion process completes in approximately 4–5 milliseconds at an engine speed of 6000 rpm. Physical intake, engine thermodynamic, and combustion models predict ignition delay, period of pre mixture at the beginning of compression in the cylinder. The air and fuel mixture ratio has to be balance to start the combustion. Therefore, combustible ignition delay and pre-mixture period outcome from this project will provided a limitation and even benchmark for improvement. Previous experiments has indicated that extremely low emissions and high efficiencies are possible if ignition of homogeneous fuel-air mixtures is accomplished. The limitations of this approach suspected to be misfiring and knock (Pradesh, 2014).
CHAPTER 2

LITERATURE REVIEW

2.1. Introduction of Bio-additives or Fuel Additives

McGraw-Hill Dictionary of Scientific & Technical Terms, Diesel Bio-additives is a compounds added to diesel fuels to improve performance, such as cetane number improvers, metal deactivators, corrosion inhibitors, antioxidants, rust inhibitors, and dispersants.

While fuel additives are largely associated with additives to gasoline, diesel and oil based fuels in the interest of environmental protection, curbing emissions and increasing mileage, the innovation around additives has a broader impact of being able to change, alter or enhance specific attributes of a fuel whether liquid, solid or gas. Additives have been developed to increase combustion rates, as anti-oxidants, to effect burn rates, to enable fuels to work under extreme temperatures, reduce harmful emissions and more. Over the years various hybrid compounds and blends have been engineered to create better fuels for industries, commercial use and end consumers alike.

2.2. Categories and Types of Bio-additives

According to a source wiki on autoropolis.com on the topic of fuel additives. The types of Bio-additives include oxygenates, ethers, antioxidants (stabilizers), antiknock agents, fuel dyes, metal deactivators, corrosion inhibitors and etc.
2.2.1. Oxygenates compound in Bio-additives

Oxygenates are fuels infused with oxygen. They are used to reduce the carbon monoxide emissions creating when burning fuel. Oxygenates can be based on either alcohol or ethers.

i). Alcohol – methanol, ethanol, isopropyl alcohol, n-butanol, and gasoline grade t-butanol

ii). Ethers – methyl tert-butyl ether, ethyl tertiary butyl ether, di isopropyl ether, tertiary amyl methyl ether, tertiary hexyl methyl ether.

2.2.2. Influences of Antioxidants in Bio-additives

Antioxidants are used as a stabilizer in fuel to prevent oxidation. Examples of some antioxidants used are:

i). Butylated hydroxytoluene

ii). 2,4-Dimethyl-6-tert-butylphenol

iii). 2,6-Di-tert-butylphenol

iv). Phenylene diamine

v). Ethylene diamine

Injector fouling tests show that multifunctional Bio-additives can reduce the injector deposit levels generated when biofuel blends are used. Specialized flow improvers are also available to address the challenging low-temperature operability profile of many biodiesel fuels, while specific antioxidants can help to stabilize the fuel against the degradation that may lead to fuel system deposits and corrosion (Trapel et al., 2005).

2.2.3. Antiknock Agents in Bio-additives

Antiknock Agents is a gasoline additive that works to reduce engine knocking while trying to increase the octane rating of the fuel. The mixture of air and gas in a traditional car engine has a problem with igniting too early and when it does, it causes a knocking noise. Some of the antiknock agents are:
i). Tetra-ethyl lead  
ii). Methyl cyclopentadienyl manganese tricarbonyl  
iii). Ferrocene  
iv). Iron pentacarbonyl  
v). Toluene  
vi). Isooctane

2.2.4. Fuel Dyes for colouring in Bio-additives

Fuel Dyes are dyes that are added to fuels. Some countries dye a fuel that is taxed at a lower rate to identify it when used incorrectly. Untaxed are the dyed fuels and taxed fuels are clear. For example, in the United Kingdom, the fuel they use for agriculture and construction vehicles are taxed at a different rate than for fuel used for commuter vehicles. They dye this fuel red. If a vehicle is found to have this fuel in it and not being used for the express purposes that it was intended for then there is a heavy penalty involved. The most often used colours are:

i). Solvent Red 24 and 26  
ii). Solvent Yellow 124  
iii). Solvent Blue 35

2.2.5. Metal deactivators effects in Bio-additives

Fuel Bio-additives and lubricant Bio-additives that are used to stabilize the fuel. It works by deactivating metal ions. Metal deactivators inhibit the formation of gummy residues. An example of a metal deactivator that is often used for gasoline is N, N’-disalicylidene-1, 2-propanediamine. This compound has been approved for both military and commercial use.

2.2.6. Corrosion inhibitors effects in Bio-additives.

Corrosion chemical compounds slow down metal corrosion. A good corrosion inhibitor will give 95% inhibition in certain circumstances. Examples of some corrosion inhibitors are sodium nitrite, hexamine, and phenylenediamine.
Bio-additives has an attraction to metal, forming a thin film which inhibits corrosion and lubricates the fuel system, (Dinesh et al., 2000). When it enters the combustion chamber, this attraction to metal is how BDF with Bio-additives penetrates the combustion deposits, removing them with each firing of the engine; even hardened ones over time. Combining a clean, lubricated engine with the combustion modifier, BDF with Bio-additive adds power, reduces emissions and provides a significant improvement in fuel economy. Keeping your engine clean and lubricated saves on maintenance costs and extends engine life. BDF with Bio-additives is also a fuel stabilizer (Vincent, 2012). BDF with Bio-additives combines a combustion modifier with a compound that has an attraction to metal which forms a thin film. This film inhibits corrosion from developing in fuel tanks and depots while lubricating the entire fuel system. BDF with Bio-additives compound's attraction to metal also makes BDF with Bio-additives penetrate combustion deposits, even hardened ones, removing them with each firing of the engine (Quigley, 2007).

Vegetable oils mainly contain triglycerides (90~98%) and traces of mono and diglycerides. Triglycerides consist of three fatty acid molecules and a glycerol molecule. They contain significant amounts of oxygen (Agarwal & Dhar, 2009). When combined with its combustion modifier, BDF with Bio-additives accelerates the fuel burn so that more of the engine's power is delivered instantaneously at the top of the piston stroke. It creates a more complete burning of fuel before the exhaust valves open which results in reduced carbon emissions, cooler exhaust temperatures and reduced valve wear. Removes combustion deposits from inside the combustion chamber, reduces formation of new deposits. Inhibits corrosion from developing in fuel tanks and systems. Keeps carburettors and injectors clean, reduces injector coking in diesel engines. Increases lubrication of fuel pump, valves, pistons and rings. Keeps exhaust systems cleaner and reduces hydrocarbon emissions Protects valves and eliminates exhaust valve seat recession in older truck engines. BDF with Bio-additives cleans up the combustion process as show below (Vincent, 2012)
Picture in Figure 2.2, above shows that the signs of fuel wash are noticeable (light colour areas around the piston edges), but greatly improved. Carbon deposits are reduced to a thin, even coating that does not build up and flake away or trap unburned fuel. The engine from which these pistons were removed was re-fitted with new high precision pistons and rings to correct the fuel wash problems and increase fuel efficiency. Use of BDF with Bio-additives is recommended with each engine to keep the combustion chambers clean and preserve the tight tolerances that make these re-fitted engines super-efficient. Both show severe signs of "fuel wash" which occurs when un-vaporized fuel enters the combustion chamber. However in Figure 2.1, in contrary show where raw unburned fuel "washed" the pistons, and caused varnish to bake onto the piston and ring surfaces (amber colour areas). The heavy carbon deposits on the piston face are caused by the incomplete fuel burn. Carbon deposits are abrasive, and so, when they break off, cause scoring of the cylinder walls and piston skirts. They also trap unburned fuel which further reduces engine efficiency and increases emissions. Test that shows how BDF with Bio-additives protects from corrosion (Vincent, 2012).

2.2.7. Others Categories in Bio-additives

There are several other fuel Bio-additives that don't fall into the same categories as the above. Some of these are:
i). **Acetone** – this is a vaporization additive. It is used, together with methanol, to improve vaporization when the engine starts up.

ii). **Nitro methane** – is used to up the engine power – commonly referred to as 'nitro.'

iii). **Ferrous picrate** is used to improve combustion and increase mileage.

iv). **And silicone**— A catalyst additive used to: Increase fuel efficiency, Clean the engine, Extend the life of the engine, Lower emissions and Anti-foaming.

Quality multifunctional diesel fuel Bio-additives have reduced many of the problems encountered with biodiesel blends, such as fuel system corrosion, water separation and increased fuel foaming. Injector fouling tests show that multifunctional additives can reduce the injector deposit levels generated when biofuel blends are used. Specialized flow improvers are also available to address the challenging low-temperature operability profile of many biodiesel fuels, while specific antioxidants can help to stabilize the fuel against the degradation that may lead to fuel system deposits and corrosion (Quigley, 2007).

![Biodiesel performance concerns](image)

*Figure 0.3: Biodiesel performance concerns (Quigley, 2007)*
Mono-alkyl ester of long chain fatty acids, known as biodiesel, is synthesized through the transesterification reaction of triglycerides derived from available, abundant and renewable feedstock, like vegetable oils and animal fats. During the reaction, these oils are alcoholised (usually by methanol) in the presence of a catalyst (usually Potassium Hydroxide - KOH) resulting in ester formation (methyl ester) and glycerine as a by-product (Mohammadi, Nikbakht, Tabatabaei, & Farhadi, 2012).

2.3. Trend in fuel Bio-additives research Patent filing

A review was made from patent filing by “Gridlogics” is an Intellectual Property (IP) Research and analysis Software Solution for intellectual property & patent management technology established by an IP Firm. In this study additive used are Silicone and Palm Methyl Ester. Silicone is one of the highest recorded IP patent filing research.

In the table 2.1 below, shows the most properties are used across different types of Fuel Bio-additives, Fuel additive types with higher number of patent filings have been highlighted with stronger shades of orange. One can see that many patents target the viscosity studies of various fuel additives including silicone as used in this experiment.
Silicone stand as one of the highest research and IP patent filing. Top assignee companies who have been the top assignees or the key players for fuel additive related Intellectual Property (IP) patents are show in figure 2.5 below.
Selecting fuel additives requires an understanding of product capabilities. Ether and other flammable hydrocarbons are used as starting fluids in hard-to-start diesel engines. Both nitrous oxide (nitrous) and nitromethane (nitro) are used in auto racing and other high-performance applications. Acetone is a vaporization additive used mainly with methane racing fuel. Butyl rubber is a detergent for diesel fuel injectors while ferox is an engine catalyst that improves fuel economy and reduces emissions in gasoline engines. Ferrous picrate and oxyhydrogen are also used to improve fuel mileage. Silicone is used as anti-foaming agent in diesel engines. Fuel additives such as tetra nitromethane can help to improve the combustion properties of diesel fuel. Fuel properties are often improved through the use of additives, which are added at the refinery, distribution, or aftermarket level. The major categories of diesel fuel additives include engine performance, fuel handling, fuel stability, and contaminant control additives.

**2.4. Bio-additives Productions**

Figure 0.5: Major Key player in the world for fuel additive related IP total Patent.
Quality improvement by the addition of additives, which has been a common practice with gasoline fuels for many years, has also become popular for diesel fuels. Depending on their purpose, diesel fuel additives can be grouped into four major categories:

i). Engine performance
ii). Fuel handling
iii). Fuel stability
iv). Contaminant control

The effects of different additives may be seen in different time frames. Some additives have an immediate effect (e.g., cetane improvers), others may bring an effect after a long period of operation (e.g., detergent additives). The overall concentration of additives is generally below 0.1%, so that the physical properties of the fuel, such as density, viscosity, and volatility are not changed.

Additives may be added to diesel fuel at three different stages: (1) at the refinery, (2) in the fuel distribution system, and (3) after the fuel has left the control of the producer. Additives of the latter group, when added by the end user or a reseller, are called “aftermarket additives”.

2.4.1. Refinery Additization.

Fuel refiners must ensure that their products meet specifications and are suitable for the intended use. This can be achieved through such means as the choice of crude oil, refinery processing, blending, or the use of additives. The final choice of methods is driven by economics. Some refineries may rely on additives, while others may be able to provide high quality fuel with no additives. Since refiners do not publish such information, the exact extent of additive usage remains unclear.

Fuel manufacturers use multiple effect additive packages, rather than single additives. In the USA, common additives include pour point reducers and fuel stability additives (Chevron, 1998).
Cetane improvers are especially common in California, to achieve the emission reductions mandated for the CARB diesel. Cloud point is usually controlled by processing changes, rather than by additives. In Europe, on the other hand, low temperature operability is often enhanced through the use of CFPP improving additives. Antifoam additives are used in Europe and Asia to prevent spills when consumers fill their tanks. Foaming is a lesser problem in North America, due to the lower distillation point of diesel fuel and different design of tanks and fuel dispensing systems. Lubricity additives are used worldwide in fuels with ultra-low sulphur content.

2.4.2. Distribution System Additization.

Pipeline operators sometimes inject drag reducing additives (to increase the pipeline capacity) and/or corrosion inhibitors. Fuel properties may be also upgraded at the terminal or even at the retail pump—such as from a regular to a ‘premium diesel’ grade—by treating the fuel with additives. An example additive package may include a detergent/dispersant, stabilizing additives, a cetane number improver, a low temperature operability additive (flow improver or pour point reducer), and a biocide (Chevron, 1998). Of course, the additive package must be always tailored to the fuel properties.

2.4.3. Aftermarket Additives.

Some users use additives to further improve the fuel to meet their particular needs, for instance cold climate operation, or because they believe they need a higher quality fuel. A wide range of aftermarket additives are available from a number of suppliers. Some of these additives may have legitimate uses. For instance, the use of de-icers may be warranted under cold weather conditions and/or when problems with fuel system icing are encountered. In many cases, however, aftermarket additives packages consist of compounds such as detergents, lubricity improvers and cetane enhancers that would normally be added at the refinery or fuel terminal by the fuel marketer.
Users should be cautious when considering the use of any aftermarket additives. Some aftermarket additives are aggressively marketed, with performance claims that are often too good to be true. Yet, in most cases, they are not needed and should be avoided. Quality commercial fuels from reputable marketers contain all the additives that a fuel needs and have been extensively tested to minimize the possibility of adverse interactions between different additive and/or fuel components.

If the user still feels that additives are needed, they should be chosen based on careful research, and used in accordance with the recommendations of the supplier and the engine manufacturer. Inappropriate use of additives may have adverse effects on the engine, and may affect engine warranties for example, some engine makers require that alcohol based de-icers not be used.

2.5. Diesel fuel Specification (Part 2: Euro 4M) review

In this study the BDF are tested and compared with the standard no 2 diesel (STD). Diesel specification under Malaysian Standard Euro 4M was developed by the Technical Committee on Petroleum Fuels under the authority of the Industry Standards Committee on Petroleum and Gas. Major modifications in this revision are as follow: Provision is made for a maximum of 7 % (v/v) of palm methyl ester (PME) to be included in diesel fuel. During the development of this standard, it is noted that specifications as recommended by ASEAN Automotive Federation cannot be fully adopted at this point of time. This Malaysian Standard cancels and replaces MS 123-2:2011 Diesel fuel - Specification - Part 1: EURO 4M. Compliance with a Malaysian Standard does not of itself confer immunity from legal obligations.
Table 0.2: Standard properties Diesel in MS Euro 4M part 2

<table>
<thead>
<tr>
<th>Property</th>
<th>Min</th>
<th>Max</th>
<th>Referee Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour (ASTM)</td>
<td>-</td>
<td>2.5</td>
<td>ASTM D 1500</td>
</tr>
<tr>
<td>Ash, mass %</td>
<td>-</td>
<td>0.01</td>
<td>ASTM D 482</td>
</tr>
<tr>
<td>Cloud point, °C</td>
<td>-</td>
<td>19</td>
<td>ASTM D 2500</td>
</tr>
<tr>
<td>Flash point, °C 60</td>
<td>60</td>
<td>-</td>
<td>ASTM D 93</td>
</tr>
<tr>
<td>Kinematic viscosity at 40°C, mm2/s</td>
<td>1.5</td>
<td>5.8</td>
<td>ASTM D 445</td>
</tr>
<tr>
<td>Copper corrosion (3h at 100 °C)</td>
<td>-</td>
<td>1</td>
<td>ASTM D 130</td>
</tr>
<tr>
<td>Water by distillation, vol. %</td>
<td>-</td>
<td>0.05</td>
<td>ASTM D 95</td>
</tr>
<tr>
<td>Sediment by extraction, mass %</td>
<td>-</td>
<td>0.01</td>
<td>ASTM D 473</td>
</tr>
<tr>
<td>Carbon residue on 10 % bottoms, mass %</td>
<td>-</td>
<td>0.02</td>
<td>ASTM D 189</td>
</tr>
<tr>
<td>Density at 15 °C, kg/l</td>
<td>0.81</td>
<td>0.87</td>
<td>ASTM D 1298</td>
</tr>
<tr>
<td>Acid number, mg KOH/g</td>
<td>-</td>
<td>0.25</td>
<td>ASTM D 664</td>
</tr>
<tr>
<td>Electrical conductivity, pS/m</td>
<td>50</td>
<td>-</td>
<td>ASTM D 2624</td>
</tr>
<tr>
<td>Cetane index</td>
<td>49</td>
<td>-</td>
<td>ASTM D 976</td>
</tr>
<tr>
<td>Cetane number</td>
<td>49</td>
<td>-</td>
<td>ASTM D 613</td>
</tr>
<tr>
<td>Physical distillation at 95 % recovered volume, °C</td>
<td>-</td>
<td>370</td>
<td>ASTM D 86</td>
</tr>
<tr>
<td>Simulated distillation at 95 % recovered mass, °C</td>
<td>-</td>
<td>399</td>
<td>ASTM D 2887</td>
</tr>
<tr>
<td>Lubricity, µm</td>
<td>-</td>
<td>460</td>
<td>ASTM D 6079</td>
</tr>
<tr>
<td>Total sulphur, mg/kg</td>
<td>-</td>
<td>50</td>
<td>ASTM D 2622</td>
</tr>
</tbody>
</table>

No intentional additions of metallic additives are allowed.

NOTES:
1. Other test methods as specified in Annex B for determining the properties may be used, provided that they have been demonstrated to give the same degree of accuracy as the test methods listed. In the event of a dispute, the test method listed in this table is to be the referee method.

2. A suitable method for the separation and identification of FAME is given in EN 14331.
2.6. Overview of Bio-additives used in the study

In this experiment, tests are monitored and validated by two fuel Bio-additives, DMPS Power that is silicone base and D20 Booster Palm Oil base. In order to investigate the effect of the DMPS and D20 as fuel additive, it’s directly pour inside the fuel tank as normal consumer do in daily circumstances. The fix volume used in the study is by 3ml in every 2 Litre of fuel. Diesel engine fuelled with BDF + additive i.e. CPO, JCO and WCO with integrated dynamometer absorber was utilized in combustion analysis and performance studies of fuel.

2.6.1. Di Methyl Poly Siloxane (DMPS Power), Silicon based Bio-additives

DMPS belongs to a group of polymeric organosilicon compounds that are commonly referred to as silicones. DMPS is the most widely used silicon-based organic polymer, and is particularly known for its unusual rheological (or flow) properties. DMPS is optically clear, and, in general, inert, non-toxic, and non-flammable. It is also called dimethicone and is one of several types of silicone oil (polymerized siloxane). Its applications range from contact lenses and medical devices to elastomers; it is also present in shampoos (as dimethicone makes hair shiny and slippery), food (antifoaming agent), caulking, lubricants, kinetic sand, and heat-resistant tiles.

![Figure 0.6: DMPS 3D and chemical formulae](https://en.wikipedia.org/wiki/Polydimethylsiloxane)

The chemical formula for PDMS is \( \text{CH}_3 [\text{Si (CH}_3)_2\text{O}]_n \text{Si (CH}_3)_3 \), where \( n \) is the number of repeating monomer \([\text{SiO (CH}_3)_3]\) units. Industrial synthesis can begin from dimethyldichlorosilane and water by the following net reaction:

- \( n \) \text{Si (CH}_3)_2\text{Cl} + n+1 \text{H}_2\text{O} \rightarrow \text{HO[-Si (CH}_3)_3\text{O-]}, \text{H} + 2n \text{HCl} \)
The polymerization reaction evolves hydrogen chloride. For medical and domestic applications, a process was developed in which the chlorine atoms in the silane precursor were replaced with acetate groups. In this case, the polymerization produces acetic acid, which is less chemically aggressive than HCl. As a side-effect, the curing process is also much slower in this case. The acetate is used in consumer applications, such as silicone caulk and adhesives. DMPS power is distributed by Glamour Power Sdn Bhd which is located in Petaling Jaya Malaysia.

2.6.2. **D20 Booster, Palm Oil based Bio-additives**

D20 Booster is distributed by D20 Resources Sdn Bhd which is located in Kajang, Selangor, Malaysia. Automotive Research Group (ARG), University Tun Hussein Onn has done an research by using this Bio-additives with booster racing formula condition, the biodiesel fuel was blended with blending ratio of 50 litre biodiesel for 1.0 ml of booster additive for all conditions. (Khalid, A. & Abas, A., 2014)

![Product Bio additive D20 Booster](image)

Figure 0.7: Product Bio additive D20 Booster

The properties of the Bio-additives also has had been measured and the result is as table 2.4 below. The BDF from CPO then blend together for the experiment conducted by the ARG UTHM researcher group.
High fuel prices, commodity grain prices, political unrest in the Middle East, a desire to go green, and global warming are reasons people consider alternative fuels. Historically, ethanol is the fuel people think of most often as an alternative fuel. However, ethanol does not work as well for agriculture and other industries because petroleum-based diesel powers many of the engines that make these segments of the economy move. Is there an alternative to petroleum diesel?

BDF can be made from a variety of renewable sources such as plant oils (soybeans, palm oil or other crops), recycled cooking grease, or animal fats. These feed stocks are used to manufacture a mixture of chemicals called fatty acid methyl esters Biodiesel is made from vegetable oils (palm oil, Jatropha, soy, canola, peanut, etc.) and animal fats (such as lard) in a process called transesterification, which involves combining fatty oils with an alcohol in the presence of a catalyst. The resulting chemical reaction produces biodiesel, glycerine, and some excess methyl alcohol.
The process is relatively simple and can be performed by individuals with specialized, but relatively simple, equipment. Fuel material produced by this process must meet the American Society for Testing and Materials (ASTM) D6751 standard to be called biodiesel. Any biodiesel conforming to this standard is safe for use in a modern diesel engine. In fact, use of biodiesel fuel that meets ASTM D6751 cannot be cited as reason to void diesel engine manufacturer warranties according to federal law. Figure 1 presents a diagram of the basic transesterification process. The notable elements in the process are that it removes glycerine from the oil and the vegetable oil or animal fat ingredient is not in a raw form.

![Diagram of the basic transesterification process](http://www.automotive-fleet.com/article/story/2008/07/industry-groups-address-expanding-biodiesel-use.aspx)

**Definition of Biodiesel transesterification:** transesterification reaction is base catalysed. Any strong base capable of deprotonating the alcohol will do (e.g. NaOH, KOH, Sodium methoxide, etc.). Commonly the base (KOH, NaOH) is dissolved in the alcohol to make a convenient method of dispersing the otherwise solid catalyst into the oil. The ROH needs to be very dry. Any water in the process promotes the saponification reaction, thereby producing salts of fatty acids (soaps) and consuming the base, and thus inhibits the transesterification reaction. Once the alcohol mixture is made, it is added to the triglyceride.
The reaction that follows replaces the alkyl group on the triglyceride in a series of steps. The carbon on the ester of the triglyceride has a slight positive charge, and the carbonyl oxygen’s have a slight negative charge. This polarization of the C=O bond is what attracts the RO- to the reaction site.

Biodiesel is defined as “mono-alkyl esters of long chain fatty acids derived from plant or animal fats.” It shares many physical properties with traditional petroleum-based diesel fuel and has roughly the same combustion quality and viscosity. Biodiesel is slightly heavier than standard No. 2 diesel and will not separate out when the two fuels are mixed. Chemically speaking, biodiesel contains 11 percent oxygen by weight. This oxygen content makes biodiesel a cleaner combusting fuel than regular diesel. The extra oxygen reduces particulate matter, hydrocarbon, and carbon monoxide emissions from combustion. Consequently, biodiesel is highly recommended for applications in which diesel engines will be operated in confined spaces, such as mines and warehouses.

![Figure 0.9: Estimated pollutant emission for various biofuels Blends](image)

With respect to greenhouse gas emissions, the actual combustion of biodiesel produces the same amount of carbon as petroleum diesel fuel. However, because the carbon in biodiesel originated from plant materials, which captured the carbon from the atmosphere, the carbon in biodiesel is considered “carbon neutral.” It does not increase the carbon dioxide content of the atmosphere.
REFERENCES


