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This issue of Palm Oil Engineering Bulletin highlights the problems related to carcinogenic 3-monochloro-1,2-propanediol (3-MCPD) in palm oil, and the use of biodiesel as alternative fuel. The role of product development and enhancement is pivotal to create sustainable products. Contaminant in palm oil, such as 3-MCPD, is given serious attention by palm oil consumers due to health risk. In relation to that, high concentrations of 3-MCPD found in refined, bleached and deodorised (RBD) palm oil should be tackled promptly. Thus, a short review on crude palm oil (CPO) dechlorination focusing on 3-MCPD issue is included in this issue. Dechlorination for 3-MCPD mitigation involves zero dilution oil clarification, CPO washing and oil neutralisation.

Biodiesel has emerged as an important alternative fuel as substitute to petroleum diesel due to the increase in oil prices and sustainability issue. Subsequent to the successful implementation of B5 and B7 programme in Malaysia, the development of B10 programme which commenced in 2014 is another alternative initiated by MPOB in collaboration with DBKL. Thus, research outcome associated to the properties of B10 diesel is included in this bulletin to provide better understanding for the palm oil industry. Technical evaluation of several brands of vehicles using B10 diesel is also depicted in this bulletin. In comparison with B7 diesel, B10 diesel shows better engine performance, reduces fuel consumption and less exhaust and smoke emission. This will contribute to cleaner environment by reducing air pollution.

This bulletin also includes an article discussing microalgae cultivation in palm oil mill effluent (POME). The large volume of effluent with high nutrient contents produced from palm oil milling activities is a potential medium for microalgae cultivation. Microalgae is suitable to be used as feedstock for biodiesel production.
as the oil extracted from microalgae contains equivalent amount of fatty acids as palm oil. A closed photobioreactor (PBR) system has been used to determine the optimum condition for cultivating microalgae in POME. The system reduces consumption of water, energy, and chemical, as well as production cost. An integrated POME treatment and microalgae cultivation may be a sustainable way to develop and enhance the production of biodiesel from microalgae.

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Note: *To be confirmed.

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Physicochemical Properties of B10 Diesel

Chee Liang Yung* and Soh Kheang Loh*

FEATURE ARTICLE

**INTRODUCTION**

The concept of using vegetable oils as fuel dated back to 1895 when the first diesel engine powered by peanut oil was developed by Dr Rudolf Diesel (Sheaves, 2001). However, the use of vegetable oil as fuel became insignificant when crude oil was discovered a few years later. Biofuel from vegetable oils once again drew world’s attention due to the energy crisis in the 1970s. With increasing concern on environment, rising oil price and rapid technological advancement, biofuel in the form of biodiesel has emerged as an important alternative fuel at present.

Biodiesel is defined as mono-alkyl esters of long chain fatty acids derived from renewable lipid sources such as vegetable oils and animal fats (ASTM International, 2015). Biodiesel is a petroleum diesel substitute, and it can be used in compression ignition engines with little or no modification. It has physical properties similar to petroleum diesel (Knothe and Dunn, 2001; Mittelbach and Remschmidt, 2004). Biodiesel is widely used as a blending stock for petroleum diesel.

MPOB has embarked on research and development of palm biodiesel or palm methyl ester (PME) way back in 1982 (Choo et al., 1997). The first pilot plant for the production of PME was constructed in 1985. Subsequently, exhaustive field trials were carried out in collaboration with various parties, in particular, the Mercedes Benz-AG, Germany. The trials have concluded that PME is a suitable substitute for petroleum diesel (Choo et al., 1997). However, due to economic reason, PME was only commercially viable and available in Malaysia in 2006. To date, 16 biodiesel plants are in operation in Malaysia with a total production capacity of 2.06 million tonnes per annum (Kushairi, 2018). B5 diesel (blends of 5% PME with 95% petroleum diesel based on volume percentage) was introduced to the petrol stations to partially replace conventional diesel in June 2011 (Yung et al., 2016). B7 diesel has subsequently replaced B5 diesel in November 2014 (Nursyairah et al., 2017). At the moment, all diesel fuels supplied in petrol stations in the country are of 7 vol.% PME blend (B7).

The government has a plan to increase the PME ratio to 10 vol.% in petroleum diesel. Hence, studies on B10 diesel in particularly the physicochemical properties is crucial for the development of the B10 diesel standard. This paper presents the properties of B10 diesel.

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die and also provides readers with a better understanding of its properties compared to neat petroleum diesel.

**ANALYSIS OF PALM BIODIESEL BLENDS**

Five neat petroleum diesel samples were obtained from five different oil companies operating a retail business in Malaysia. Eight PME samples were obtained from PME producers in the country. The petroleum diesel samples were labelled as Diesel A to Diesel E while the PME samples were labelled as PME 1 to PME 8.

B10 diesel samples were prepared by blending 10 vol.% of PME 1 to PME 8 with 90 vol.% of Diesel A to Diesel E. The B10 diesel samples were labelled accordingly, *e.g.* Diesel A with PME 1 as A1, Diesel A with PME 2 as A2, Diesel A with PME 3 as A3, *etc.* The petroleum diesel and B10 diesel samples were subjected to physicochemical property analyses according to the parameters stipulated in the Malaysian standard specification for diesel fuel, MS123-1:2014 (Department of Standards Malaysia, 2014). Table 1 lists the test methods for the analyses of each parameter and their limits. The obtained properties of B10 diesel samples were compared with the respective neat diesel.

**PROPERTIES OF NEAT PETROLEUM DIESEL**

There are two grades of petroleum diesel supplied to the Malaysian market, the Euro 2M diesel and Euro 5 diesel. Euro 2M diesel is the mandatory diesel supplied in every petrol station while Euro 5 diesel is supplied voluntarily by oil companies in selected petrol stations. The main difference between them is the maximum limit of sulphur content: 500 mg kg$^{-1}$ and 10 mg kg$^{-1}$ for Euro 2M diesel and Euro 5 diesel, respectively. As the sulphur content differs significantly, Euro 5 diesel is considered much cleaner than Euro 2M diesel with regards to exhaust emissions of the vehicles. As mentioned earlier, currently both the Euro

<table>
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<th>Property</th>
<th>Method</th>
<th>Unit</th>
<th>Limit</th>
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<tbody>
<tr>
<td>Colour (ASTM)</td>
<td>ASTM D1500</td>
<td>-</td>
<td>2.5 max</td>
</tr>
<tr>
<td>Ash</td>
<td>ASTM D482</td>
<td>mass %</td>
<td>0.01 max</td>
</tr>
<tr>
<td>Cloud point</td>
<td>ASTM D2500</td>
<td>°C</td>
<td>19.0 max</td>
</tr>
<tr>
<td>Flash point</td>
<td>ASTM D93</td>
<td>°C</td>
<td>60 min</td>
</tr>
<tr>
<td>Kinematic viscosity at 40°C</td>
<td>ASTM D445</td>
<td>mm$^2$ s$^{-1}$</td>
<td>1.5-5.8</td>
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<td>Copper corrosion (3 h at 100°C)</td>
<td>ASTM D130</td>
<td>Rating</td>
<td>1 max</td>
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<td>Water by distillation</td>
<td>ASTM D95</td>
<td>vol. %</td>
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<tr>
<td>Water content</td>
<td>ISO 12937</td>
<td>mg kg$^{-1}$</td>
<td>-</td>
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<tr>
<td>Sediment by extraction</td>
<td>ASTM D473</td>
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<td>Carbon residue on 10% bottoms</td>
<td>ASTM D189</td>
<td>mass %</td>
<td>0.2 max</td>
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<td>Density at 15°C</td>
<td>ASTM D4052</td>
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<td>Electrical conductivity</td>
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<td>Physical distillation at 95% recovered volume</td>
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<td>°C</td>
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<td>Cetane number</td>
<td>ASTM D6890</td>
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<tr>
<td>Lubricity</td>
<td>ASTM D6079</td>
<td>μm</td>
<td>460 max</td>
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<tr>
<td>Total sulphur</td>
<td>ASTM D5453</td>
<td>mg kg$^{-1}$</td>
<td>500 max</td>
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</table>
2M diesel and Euro 5 diesel supplied in petrol stations nationwide consist of 7 vol.% of PME (Nursyairah et al., 2017).

As Euro 5 diesel is not commonly used, our evaluation focused on the effect of 10 vol.% of PME to the quality of Euro 2M diesel. The sulphur content of Diesel A to Diesel E samples ranged 288 mg kg\(^{-1}\)-426 mg kg\(^{-1}\) (Table 2-Table 6), meeting the Malaysian standard MS 123-1:2014 as well as the Regulation 4(1)(b) of the Environmental Quality (Control of Petrol and Diesel Properties) Regulations 2007 (Table 7).

Some distinct differences were observed for Diesel C compared with other diesel samples. Diesel C possessed a much higher cloud point of 16°C than the other four diesel fuels (<10°C) but still within the limit set at 19°C maximum in MS 123:1:2014. Diesel with high cloud point is known to be unsuitable for cold climate conditions. However, this is not an issue for hot climate countries like Malaysia. The presence of more straight chain paraffinic hydrocarbons which further led to a higher derived cetane number (DCN) was anticipated as the cause of high cloud point in Diesel C (Table 4). In summary, all the five petroleum diesel samples available commercially are in full compliance with the MS 123-1:2014.

### PROPERTIES OF B10 DIESEL

All the petroleum diesel samples were blended separately with 10 vol.% PME 1 to PME 8. Their properties are presented in Table 2. In general, all the B10 diesel samples complied with the requirements stipulated in the MS123-1:2014. No significant changes

**TABLE 2. PROPERTIES OF B10 DIESEL**

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<th>Property</th>
<th>Test method</th>
<th>Unit</th>
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<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>A6</th>
<th>A7</th>
<th>A8</th>
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<td>Colour (ASTM)</td>
<td>ASTM D1500</td>
<td>-</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L0.5</td>
</tr>
<tr>
<td>Ash</td>
<td>ASTM D482</td>
<td>mass %</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
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<td>&lt;0.001</td>
</tr>
<tr>
<td>Cloud point</td>
<td>ASTM D2500</td>
<td>°C</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
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<tr>
<td>Flash point</td>
<td>ASTM D93</td>
<td>°C</td>
<td>80.0</td>
<td>81.0</td>
<td>82.0</td>
<td>81.0</td>
<td>82.0</td>
<td>81.0</td>
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<td>73.0</td>
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<tr>
<td>Copper corrosion (3 h at 100°C)</td>
<td>ASTM D130</td>
<td>Rating</td>
<td>1a</td>
<td>1a</td>
<td>1b</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>1b</td>
<td>1a</td>
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<tr>
<td>Water by distillation</td>
<td>ASTM D95</td>
<td>vol. %</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
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<tr>
<td>Water content</td>
<td>ISO 12937</td>
<td>mg kg(^{-1})</td>
<td>84</td>
<td>107</td>
<td>108</td>
<td>87</td>
<td>106</td>
<td>102</td>
<td>118</td>
<td>121</td>
<td>95</td>
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<tr>
<td>Sediment by extraction</td>
<td>ASTM D473</td>
<td>mass %</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
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<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
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<tr>
<td>Carbon residue on 10% bottoms</td>
<td>ASTM D189</td>
<td>mass %</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Density at 15°C</td>
<td>ASTM D4052</td>
<td>kg L(^{-1})</td>
<td>0.8441</td>
<td>0.8469</td>
<td>0.8470</td>
<td>0.8470</td>
<td>0.8470</td>
<td>0.8470</td>
<td>0.8470</td>
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<td>0.8470</td>
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<tr>
<td>Acid number</td>
<td>ASTM D664</td>
<td>mg KOH g(^{-1})</td>
<td>0.02</td>
<td>0.03</td>
<td>0.02</td>
<td>0.04</td>
<td>0.03</td>
<td>0.04</td>
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<td>0.03</td>
<td>0.04</td>
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<tr>
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<td>ASTM D2624</td>
<td>pS m(^{-1})</td>
<td>197</td>
<td>200</td>
<td>244</td>
<td>230</td>
<td>267</td>
<td>253</td>
<td>207</td>
<td>253</td>
<td>251</td>
</tr>
<tr>
<td>Physical distillation at 95% recovered volume</td>
<td>ASTM D86</td>
<td>°C</td>
<td>359</td>
<td>360</td>
<td>360</td>
<td>360</td>
<td>360</td>
<td>356</td>
<td>360</td>
<td>359</td>
<td>357</td>
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<tr>
<td>Cetane number</td>
<td>ASTM D6890</td>
<td>-</td>
<td>51.5</td>
<td>53.1</td>
<td>55.6</td>
<td>54.4</td>
<td>54.5</td>
<td>54.1</td>
<td>53.5</td>
<td>54.3</td>
<td>53.3</td>
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<tr>
<td>Lubricity</td>
<td>ASTM D6079</td>
<td>μm</td>
<td>411.5</td>
<td>156.0</td>
<td>162.0</td>
<td>292.0</td>
<td>176.0</td>
<td>317.5</td>
<td>188.5</td>
<td>200.5</td>
<td>170.5</td>
</tr>
<tr>
<td>Total sulphur</td>
<td>ASTM D5453</td>
<td>mg kg(^{-1})</td>
<td>426</td>
<td>391</td>
<td>387</td>
<td>388</td>
<td>388</td>
<td>387</td>
<td>387</td>
<td>371</td>
<td>390</td>
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TABLE 3. PROPERTIES OF B10 DIESEL B

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<thead>
<tr>
<th>Properties</th>
<th>Test method</th>
<th>Unit</th>
<th>Diesel B</th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
<th>B4</th>
<th>B5</th>
<th>B6</th>
<th>B7</th>
<th>B8</th>
</tr>
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<tbody>
<tr>
<td>Colour (ASTM)</td>
<td>ASTM D1500</td>
<td></td>
<td>L0.5</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L1.0</td>
<td>L1.0</td>
<td>L1.0</td>
<td>L1.0</td>
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<tr>
<td>Ash</td>
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<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
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<tr>
<td>Cloud point</td>
<td>ASTM D2500 °C</td>
<td></td>
<td>6</td>
<td>9</td>
<td>5</td>
<td>6</td>
<td>9</td>
<td>6</td>
<td>6</td>
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<td>7</td>
</tr>
<tr>
<td>Flash point</td>
<td>ASTM D93 °C</td>
<td></td>
<td>75.0</td>
<td>76.0</td>
<td>76.0</td>
<td>76.0</td>
<td>76.0</td>
<td>75.0</td>
<td>77.0</td>
<td>67.0</td>
<td>78.0</td>
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<tr>
<td>Copper corrosion (3 hr at 100°C)</td>
<td>ASTM D130 Rating</td>
<td></td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
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<td>1a</td>
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<tr>
<td>Water by distillation</td>
<td>ASTM D95 vol. %</td>
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<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Water content</td>
<td>ISO 12937 mg kg⁻¹</td>
<td></td>
<td>72</td>
<td>112</td>
<td>122</td>
<td>88</td>
<td>105</td>
<td>97</td>
<td>82</td>
<td>148</td>
<td>115</td>
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<tr>
<td>Sediment by extraction</td>
<td>ASTM D473 mass %</td>
<td></td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
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<tr>
<td>Carbon residue on 10% bottoms</td>
<td>ASTM D189 mass %</td>
<td></td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
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<tr>
<td>Density at 15°C</td>
<td>ASTM D4052 kg L⁻¹</td>
<td></td>
<td>0.8449</td>
<td>0.8523</td>
<td>0.8521</td>
<td>0.8522</td>
<td>0.8523</td>
<td>0.8522</td>
<td>0.8522</td>
<td>0.8519</td>
<td>0.8525</td>
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<tr>
<td>Acid number</td>
<td>ASTM D664 mg KOH g⁻¹</td>
<td></td>
<td>&lt;0.02</td>
<td>0.03</td>
<td>0.02</td>
<td>0.04</td>
<td>0.03</td>
<td>0.03</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Electrical conductivity</td>
<td>ASTM D2624 pS m⁻¹</td>
<td></td>
<td>87</td>
<td>98</td>
<td>126</td>
<td>108</td>
<td>126</td>
<td>92</td>
<td>82</td>
<td>69</td>
<td>72</td>
</tr>
<tr>
<td>Physical distillation at 9% recovered volume</td>
<td>ASTM D86 °C</td>
<td></td>
<td>368</td>
<td>364</td>
<td>365</td>
<td>364</td>
<td>353</td>
<td>365</td>
<td>365</td>
<td>365</td>
<td>364</td>
</tr>
<tr>
<td>Cetane number</td>
<td>ASTM D6890</td>
<td>-</td>
<td>51.8</td>
<td>53.9</td>
<td>56.3</td>
<td>55.0</td>
<td>56.2</td>
<td>54.4</td>
<td>53.8</td>
<td>59.2</td>
<td>59.3</td>
</tr>
<tr>
<td>Lubricity</td>
<td>ASTM D6079 μm</td>
<td></td>
<td>362</td>
<td>166.5</td>
<td>121.5</td>
<td>297</td>
<td>182.5</td>
<td>285.5</td>
<td>172.5</td>
<td>176.0</td>
<td>164.0</td>
</tr>
<tr>
<td>Total sulphur</td>
<td>ASTM D5453 mg kg⁻¹</td>
<td></td>
<td>409</td>
<td>372</td>
<td>374</td>
<td>373</td>
<td>367</td>
<td>375</td>
<td>377</td>
<td>362</td>
<td>369</td>
</tr>
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</table>

were observed in their properties except for slight increases though insignificant in cloud point, kinematic viscosity, water content, density and acid number. On top of that, approximately 10% reduction in sulphur content was observed in all B10 samples, mainly attributed to the low sulphur content exhibited by PME itself, i.e. <10 mg kg⁻¹ (Yung et al., 2013)

Cetane number is a prime indicator in assessing the quality of diesel fuel. Its minimum is 49 to meet the MS123-1:2014 requirement and the Regulation 4(1)(b) of the Environmental Quality (Control of Petrol and Diesel Properties) Regulations 2007. As palm biodiesel is a cetane improver (Yung et al., 2016), its presence in B10 samples shows great improvement in DCN from 0.2% to 6% higher than petroleum diesel (Diesel A to Diesel E).

Diesel engines rely on the lubrication property of the fuel to lubricate some of the important engine parts such as fuel pumps and fuel injectors (Knothe, 2010). The lubricity characteristics of a diesel fuel are crucial to safeguard the durability and smooth operation of the engine components. This lubricity property can be assessed based on the wear scar diameter (WSD) generated on a steel ball using a high-frequency reciprocating rig. A small WSD indicates better lubricity of a diesel fuel. In this study, the WSD recorded for B10 diesel samples was significantly smaller; with 12% to 66% reduction compared to petroleum diesel.
### TABLE 4. PROPERTIES OF B10 DIESEL C

<table>
<thead>
<tr>
<th>Property</th>
<th>Test method</th>
<th>Unit</th>
<th>Diesel C</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
<th>C8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Colour (ASTM)</td>
<td>ASTM D1500</td>
<td>-</td>
<td>1.0</td>
<td>0.5</td>
<td>1.0</td>
<td>0.5</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>2. Ash</td>
<td>ASTM D482</td>
<td>mass %</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
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<td>3. Cloud point</td>
<td>ASTM D2500</td>
<td>°C</td>
<td>14</td>
<td>14</td>
<td>13</td>
<td>12</td>
<td>14</td>
<td>14</td>
<td>15</td>
<td>15</td>
<td>15</td>
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<tr>
<td>4. Flash point</td>
<td>ASTM D93</td>
<td>°C</td>
<td>65.0</td>
<td>65.0</td>
<td>65.0</td>
<td>65.0</td>
<td>65.0</td>
<td>65.0</td>
<td>59.0</td>
<td>67.0</td>
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<td>5. Kinematic viscosity at 40°C</td>
<td>ASTM D445</td>
<td>mm²s⁻¹</td>
<td>2.888</td>
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<td>3.005</td>
<td>2.996</td>
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<td>2.999</td>
<td>2.999</td>
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<td>6. Copper corrosion (3 hr at 100°C)</td>
<td>ASTM D130</td>
<td>Rating</td>
<td>1a</td>
<td>1b</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
</tr>
<tr>
<td>7. Water by distillation</td>
<td>ASTM D95</td>
<td>vol. %</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>8. Water content</td>
<td>ISO 12937</td>
<td>mg kg⁻¹</td>
<td>64</td>
<td>92</td>
<td>114</td>
<td>92</td>
<td>96</td>
<td>103</td>
<td>91</td>
<td>122</td>
<td>91</td>
</tr>
<tr>
<td>9. Sediment by extraction on 10% bottoms</td>
<td>ASTM D473</td>
<td>mass %</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
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<tr>
<td>10. Carbon residue on 10% bottoms</td>
<td>ASTM D189</td>
<td>mass %</td>
<td>&lt;0.1</td>
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<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
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<tr>
<td>11. Density at 15°C</td>
<td>ASTM D4052</td>
<td>kg L⁻¹</td>
<td>0.8333</td>
<td>0.8372</td>
<td>0.8372</td>
<td>0.8372</td>
<td>0.8373</td>
<td>0.8373</td>
<td>0.8372</td>
<td>0.8368</td>
<td>0.8373</td>
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<td>12. Acid number</td>
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<td>0.09</td>
<td>0.10</td>
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<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
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<tr>
<td>13. Electrical conductivity</td>
<td>ASTM D2624</td>
<td>pS m⁻¹</td>
<td>328</td>
<td>291</td>
<td>399</td>
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<td>432</td>
<td>417</td>
<td>299</td>
<td>547</td>
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<td>14. Physical distillation at 95% recovered volume</td>
<td>ASTM D86</td>
<td>°C</td>
<td>365</td>
<td>365</td>
<td>364</td>
<td>364</td>
<td>363</td>
<td>365</td>
<td>364</td>
<td>364</td>
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<td>15. Cetane number</td>
<td>ASTM D6890</td>
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<td>58.3</td>
<td>58.5</td>
<td>58.7</td>
<td>58.4</td>
<td>58.9</td>
<td>59.0</td>
<td>58.6</td>
<td>60.6</td>
<td>59.7</td>
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<tr>
<td>16. Lubricity</td>
<td>ASTM D6079</td>
<td>µm</td>
<td>347.5</td>
<td>194.5</td>
<td>182.5</td>
<td>300.0</td>
<td>177.5</td>
<td>304.5</td>
<td>190.0</td>
<td>206.5</td>
<td>186.5</td>
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<td>17. Total sulphur</td>
<td>ASTM D5453</td>
<td>mg kg⁻¹</td>
<td>338</td>
<td>308</td>
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<td>304</td>
<td>306</td>
<td>321</td>
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</tbody>
</table>

### CONCLUSION

Based on the properties evaluated, all the B10 diesel samples are within the parameter limits stipulated in the MS 123-1:2014. As such, B10 diesel can be suitably used as diesel fuel to improve the performance of diesel engines with added advantages of better DCN and lubricity characteristics.

### ACKNOWLEDGEMENT

The authors wish to thank the Director-General of MPOB for permission to publish this paper. Sincere thanks are also attributed to the oil companies and PME producers for supplying the samples for the study.

### REFERENCES


# TABLE 5. PROPERTIES OF B10 DIESEL D

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<tr>
<th>Properties</th>
<th>Test method</th>
<th>Unit</th>
<th>Diesel D</th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>D4</th>
<th>D5</th>
<th>D6</th>
<th>D7</th>
<th>D8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Colour (ASTM)</td>
<td>ASTM D1500</td>
<td>-</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L1.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2. Ash</td>
<td>ASTM D482</td>
<td>mass %</td>
<td>&lt;0.001 &lt;0.001 &lt;0.001 &lt;0.001 &lt;0.001 &lt;0.001 &lt;0.001</td>
<td>-</td>
<td>-</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Cloud point ASTM D2500</td>
<td>°C</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>4</td>
<td>7</td>
<td>5</td>
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<td>-</td>
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<td></td>
</tr>
<tr>
<td>4. Flash point ASTM D93</td>
<td>°C</td>
<td>72.0</td>
<td>75.0</td>
<td>74.0</td>
<td>74.0</td>
<td>76.0</td>
<td>76.0</td>
<td>75.0</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>5. Kinematic viscosity at 40°C ASTM D445</td>
<td>mm² s⁻¹</td>
<td>3.644</td>
<td>3.692</td>
<td>3.696</td>
<td>3.684</td>
<td>3.692</td>
<td>3.689</td>
<td>3.689</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>6. Copper corrosion (3 h at 100°C) ASTM D130</td>
<td>Rating</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>7. Water by distillation ASTM D95</td>
<td>vol. %</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>8. Water content ISO 12937</td>
<td>mg kg⁻¹</td>
<td>72</td>
<td>99</td>
<td>114</td>
<td>92</td>
<td>104</td>
<td>96</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>9. Sediment by extraction ASTM D473</td>
<td>mass %</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>10. Carbon residue on 10% bottoms ASTM D189</td>
<td>mass %</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>0.10</td>
<td>0.10</td>
<td>-</td>
</tr>
<tr>
<td>11. Density at 15°C ASTM D4052</td>
<td>kg L⁻¹</td>
<td>0.8451</td>
<td>0.8479</td>
<td>0.8477</td>
<td>0.8478</td>
<td>0.8479</td>
<td>0.8479</td>
<td>0.8479</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>12. Acid number ASTM D664</td>
<td>mg KOH g⁻¹</td>
<td>0.04</td>
<td>0.06</td>
<td>0.05</td>
<td>0.07</td>
<td>0.06</td>
<td>0.07</td>
<td>0.07</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>13. Electrical conductivity ASTM D2624</td>
<td>pS m⁻¹</td>
<td>512</td>
<td>537</td>
<td>817</td>
<td>782</td>
<td>809</td>
<td>815</td>
<td>559</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>14. Physical distillation at 95% recovered volume ASTM D86</td>
<td>°C</td>
<td>362</td>
<td>358</td>
<td>359</td>
<td>358</td>
<td>358</td>
<td>357</td>
<td>358</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>15. Cetane number ASTM D6890</td>
<td>-</td>
<td>52.0</td>
<td>53.6</td>
<td>54.5</td>
<td>53.4</td>
<td>55.0</td>
<td>53.7</td>
<td>52.9</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>16. Lubricity ASTM D6079</td>
<td>μm</td>
<td>357.5</td>
<td>186.5</td>
<td>164.5</td>
<td>240.5</td>
<td>178.0</td>
<td>308.0</td>
<td>174.0</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>17. Total sulphur ASTM D5453</td>
<td>mg kg⁻¹</td>
<td>408</td>
<td>372</td>
<td>372</td>
<td>365</td>
<td>361</td>
<td>367</td>
<td>374</td>
<td>-</td>
<td>-</td>
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</tr>
</tbody>
</table>


Nursyairah, J; Lau, H L N; Loh, S K; Rusnani, A M; Daryl, J T; Yung, C L; Ropandi, M; Wan Hasamudin, W H; Pua, C W; Yahaya, H; Noraida, O; Astimar, A A and Lim, W S...
### TABLE 6. PROPERTIES OF B10 DIESEL E

<table>
<thead>
<tr>
<th>Property</th>
<th>Test method</th>
<th>Unit</th>
<th>Diesel E</th>
<th>E1</th>
<th>E2</th>
<th>E3</th>
<th>E4</th>
<th>E5</th>
<th>E6</th>
<th>E7</th>
<th>E8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Colour (ASTM)</td>
<td>ASTM D1500</td>
<td>-</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L0.5</td>
<td>L1.0</td>
<td>L0.5</td>
<td>L0.5</td>
</tr>
<tr>
<td>2. Ash</td>
<td>ASTM D482</td>
<td>mass %</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>3. Cloud point</td>
<td>ASTM D2500</td>
<td>°C</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>7</td>
<td>8</td>
<td>7</td>
<td>7</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>4. Flash point</td>
<td>ASTM D93</td>
<td>°C</td>
<td>65.0</td>
<td>68.0</td>
<td>67.0</td>
<td>67.0</td>
<td>70.0</td>
<td>68.0</td>
<td>69.0</td>
<td>62.0</td>
<td>69.0</td>
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<tr>
<td>6. Copper corrosion (3 h at 100°C)</td>
<td>ASTM D130</td>
<td>Rating</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
<td>1b</td>
</tr>
<tr>
<td>7. Water by distillation</td>
<td>ASTM D95</td>
<td>vol. %</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>8. Water content</td>
<td>ISO 12937</td>
<td>mg kg⁻¹</td>
<td>88</td>
<td>122</td>
<td>122</td>
<td>101</td>
<td>116</td>
<td>110</td>
<td>108</td>
<td>140</td>
<td>110</td>
</tr>
<tr>
<td>9. Sediment by extraction</td>
<td>ASTM D473</td>
<td>mass %</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>10. Carbon residue on 10% bottoms</td>
<td>ASTM D189</td>
<td>mass %</td>
<td>&lt;0.1</td>
<td>0.10</td>
<td>0.10</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>11. Density at 15°C</td>
<td>ASTM D4052</td>
<td>kg L⁻¹</td>
<td>0.8554</td>
<td>0.8572</td>
<td>0.8571</td>
<td>0.8572</td>
<td>0.8572</td>
<td>0.8572</td>
<td>0.8572</td>
<td>0.8567</td>
<td>0.8573</td>
</tr>
<tr>
<td>12. Acid number</td>
<td>ASTM D664</td>
<td>mg KOH g⁻¹</td>
<td>&lt;0.02</td>
<td>0.04</td>
<td>0.02</td>
<td>0.04</td>
<td>0.03</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>13. Electrical conductivity</td>
<td>ASTM D2624</td>
<td>pS m⁻¹</td>
<td>685</td>
<td>642</td>
<td>845</td>
<td>842</td>
<td>879</td>
<td>922</td>
<td>635</td>
<td>1219</td>
<td>1146</td>
</tr>
<tr>
<td>15. Cetane number</td>
<td>ASTM D6810</td>
<td>-</td>
<td>52.3</td>
<td>53.3</td>
<td>53.0</td>
<td>52.6</td>
<td>52.6</td>
<td>53.1</td>
<td>54.4</td>
<td>54.4</td>
<td>53.8</td>
</tr>
<tr>
<td>16. Lubricity</td>
<td>ASTM D6079</td>
<td>μm</td>
<td>369.5</td>
<td>166.5</td>
<td>152.0</td>
<td>309.5</td>
<td>165.5</td>
<td>317.5</td>
<td>175.0</td>
<td>166.5</td>
<td>174.0</td>
</tr>
<tr>
<td>17. Total sulphur</td>
<td>ASTM D5453</td>
<td>mg kg⁻¹</td>
<td>288</td>
<td>263</td>
<td>261</td>
<td>259</td>
<td>258</td>
<td>258</td>
<td>257</td>
<td>251</td>
<td>253</td>
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</tbody>
</table>

### TABLE 7. PROPERTIES REGULATED IN 4(1)(B) OF THE ENVIRONMENTAL QUALITY (CONTROL OF PETROL AND DIESEL PROPERTIES) REGULATIONS 2007

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Density at 15°C</td>
<td>kg L⁻¹</td>
<td>0.81-0.87</td>
</tr>
<tr>
<td>2. Cetane number or cetane index</td>
<td>-</td>
<td>49 min</td>
</tr>
<tr>
<td>3. Physical distillation at 95% recovered volume</td>
<td>°C</td>
<td>370 max</td>
</tr>
<tr>
<td>4. Total sulphur</td>
<td>mg kg⁻¹</td>
<td>500 max</td>
</tr>
</tbody>
</table>

Source: ILBS (2014).
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Raw sludge filter through AquaEco Reactor produces a clear Filtrate with negligible oil and suspended solids.

COD/BOD of discharge is reduced by 65% to 75%. Increase Oil Extraction Rate (OER) of mill.

Payback in 2 to 3 years.

Suspended solid removed as decanter cake.

Concentrate to Decanter

Raw Sludge
AquaEco Reactor
Filtrate

Analysis Results

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>Test Methods</th>
<th>Results</th>
<th>POME</th>
<th>Filtrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH Value</td>
<td>APHA 4500-H B</td>
<td>4.73 @ 25.6°C</td>
<td>4.69 @ 25.6°C</td>
<td></td>
</tr>
<tr>
<td>Biochemical Oxygen Demand (3 Days @ 30°C), mg/L</td>
<td>DL-LAB-TM01 (based on MN Method B-22)</td>
<td>48.100</td>
<td>13,410</td>
<td></td>
</tr>
<tr>
<td>Chemical Oxygen Demand, mg/L</td>
<td>DL-LAB-TM02 (based on MN Method 0-25; 0-28; 0-29)</td>
<td>78,000</td>
<td>19,300</td>
<td></td>
</tr>
<tr>
<td>Ammonial Nitrogen (NH₃-N), mg/L</td>
<td>DL-LAB-TM03 (based on MN Method 1-05)</td>
<td>70</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Total Nitrogen, mg/L</td>
<td>DL-LAB-TM04 (based on MN Method 0-88)</td>
<td>590</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Oil and Grease, mg/L</td>
<td>DOE (M) Reference Method</td>
<td>13,812</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Suspended Solids, mg/L</td>
<td>DOE (M) Alternative Method</td>
<td>24,600</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Total Solids, mg/L</td>
<td>APHA 2540 B</td>
<td>49,750</td>
<td>20,760</td>
<td></td>
</tr>
</tbody>
</table>

BOD 70% Reduction
COD 75% Reduction
Oil is almost non-detectable
99.90% of Suspended Solids removed

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MSB CLUTCH DOOR 8000D-32000D

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MSB CAGE TRANSPORT CAR / TRANSFER CARRIAGE

MSB CAGE TIPPER
Feature Article

Microalgae Cultivation In Palm Oil Mill Effluent (POME)

Nur Azreena Idris*; Soh Kheang Loh* and Harrison Lik Nang Lau*

ABSTRACT

Developing alternative fuels is an essential step towards solving fossil fuels issues such as fuel cost and pollution. Microalgae can be a promising feedstock for alternative fuel as it is fast growing and easily cultivated. Exploring wastewater such as palm oil mill effluent (POME) for feasible microalgae cultivation is essential as POME is abundantly available from palm oil milling activities. The high content of nutrients in POME makes it a potential microalgae growth medium. This study demonstrated that a microalgae species, i.e. Chlorella vulgaris UMACC 001 can grow at a specific growth rate of 0.39 day\(^{-1}\) and produce 0.14 mg biomass litre day\(^{-1}\) in POME outdoor conditions. The extracted algal oil showed 48.9% saturated fatty acids and 51.1% unsaturated fatty acids equivalent to palm oil as a biodiesel feedstock.

INTRODUCTION

Oil palm products such as palm oil, palm kernel oil, palm kernel cake, oleochemicals, finished products and biodiesel have contributed to RM 77.8 billion of export revenues in 2017. Approximately, 17.89 t ha\(^{-1}\) of fresh fruit bunch (FFB) was produced leading to 101.02 million tonnes of annual FFB processing from a total of 454 palm oil mills. Malaysia covers about 30% of the world’s palm oil production and 34% of palm oil exports (Kushairi et al., 2018). The high production of FFB yields 19.92 million tonnes of crude palm oil (CPO), and huge quantity of by-product, i.e. palm oil mill effluent (POME). POME is rich in organic matter but could be contaminated due to high content of biological oxygen demand (BOD), chemical oxygen demand (COD), oil and grease, total solids and suspended solids (Loh et al., 2013). About 0.75 tonnes of POME is generated for every tonne of FFB processed (Vairappan and Yen, 2008). Technologies for POME treatment consist of conventional biological treatment methods, i.e. acidification, anaerobic, facultative and aerobic.
degradation (Loh et al., 2013), open and closed digester tank with biogas recovery (Vairappan and Yen, 2008), and more recently an integrated biological treatment process is introduced consisting of pre-treatment, biological treatment and membrane separation (Loh et al., 2013). Microalgae, a potential substrate for the production of biofuel, can be cultivated using POME as cultivation medium since it provides nitrogen and phosphorus to produce lipids and proteins (He et al., 2013).

Biofuels can potentially be an alternative energy to replace fossil fuels. In particular, biofuels derived from microalgae are termed as the third generation biofuel. Microalgae are photosynthetic prokaryotic or eukaryotic microorganisms that grow rapidly when sunlight, water, carbon dioxide (CO₂) and nutrients are available and have the ability to live in different environments due to their unicellular or simple multicellular structure and simple growth needs (Chisti, 2007). This enormous growth potential contributes biomass for food, feed, fine chemicals and biofuels as well. They produce lipids, protein and carbohydrates that are common metabolite for bio conversion into both biofuels and valuable co-products. It is envisaged that microalgae have higher biomass productivity than plant crops based on land area required for cultivation and hold potential in greenhouse gas (GHG) emissions reduction.

Microalgal biomass can be produced either in closed or open systems. It is more economical for the latter but with less control of contamination from predators while the former has better control of nutrients and cultivation parameters such as temperature, dissolved CO₂, pH and lighting (Moreno-Garcia et al., 2017). The ability of these microorganisms to produce and accumulate energy molecules (lipids) and their cells, plus the fact that their growth has no impact on agriculture have made them a promising feedstock for biofuels.

Different microalgal species accumulate varying quantities of lipids. The highest lipid yielding species reported so far are Botryococcus braunii, Desmodesmus sp., Nannochloropsis sp., Scenedesmus SDEC-8, Nannochloropsis sp., and Sorokiniana FCG IITG with 45%-64% lipid contents (dry weight) which are convertible into biofuel. Chlorella vulgaris stands up as one of the most attractive feedstock for biofuels owing to its fast growth and easy cultivation (Al-lwayzy et al., 2014). As a suitable biofuel feedstock, species of microalgae must have high specific growth rate, high lipid content and robust, i.e. survive well in stressful environment caused by lack of heat, nutrient input and light intensity, and contamination from bacteria. The biomass harvesting process and lipid extraction method must be simple and economical too (Hannon et al., 2010). This paper investigates and identifies the potential of POME as a low-cost cultivation medium for microalgae obtained from UM culture collection, i.e. Chlorella vulgaris UMACC 001 and the resulting algal oil as a biodiesel feedstock.

### CULTIVATION OF MICROALGAE IN POME

The nutrients for cultivation (mainly nitrogen and phosphorus) can be obtained from POME, therefore besides providing a suitable growth environment for microalgae, POME is potentially degraded and polished to lower its organic contents. Since the palm oil industry generates around 65 million tonnes of POME a year, the wastewater discharged into waterways should be properly managed due to high BOD which causes depletion of dissolved oxygen. At the same time, the POME also contains high concentrations of protein, carbohydrate, nitrogenous compounds, lipids and minerals that can be utilised as food source for aquatic life (Habib et al., 1997). Table 1 shows the characteristic of raw POME and treated POME via anaerobic digestion. Raw POME has higher content of total solid (TS) (≈60175 mg litre⁻¹) and COD (≈74900 mg litre⁻¹), and these are much reduced in the treated POME, hence providing a neutral medium for microalgae cultivation with sufficient dissolved oxygen. Furthermore, the acidic characteristic and dark colour of raw POME may also reduce light availability and cause low growth.
starts to decrease, leading to accumulation of lipids (Mansour et al., 2005). As POME is naturally colloidal, viscous and dark, it has to be diluted prior to media preparation for microalgae culture. Dilution also reduces the rather high concentration of ammoniacal nitrogen of POME that microalgae might not tolerate (Bello et al., 2013). A 5% diluted POME has been found suitable for culturing marine microalgae species, Isochrysis sp. (Vairappan and Yen, 2008).

The optimisation of microalgae cultivation conditions is related to factors such as temperature, mixing, fluid dynamics and hydrodynamic stress, gas bubble size and distribution, gas exchange, mass transfer, light cycle and intensity, water quality, pH, salinity, mineral and cell density and growth inhibition (Schenk et al., 2008). Optimal media formulation is important to ensure sufficient and stable supply of nutrients for microalgae to reach maximum growth acceleration and cell density, and to produce good quality biofuel feedstocks (Dayananda et al., 2005). The majority of microalgae cultivated today are grown in open ponds due to economic advantages and ease of maintenance. The main disadvantages of open ponds are rapid water evaporation rate and susceptible to contamination by unwanted species as they are largely exposed to the atmosphere (Schenk et al., 2008).

<table>
<thead>
<tr>
<th>TABLE 1. POME CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>pH</td>
</tr>
<tr>
<td>Chemical oxygen demand (COD)</td>
</tr>
<tr>
<td>Total solid (TS)</td>
</tr>
<tr>
<td>Total suspended solid (TSS)</td>
</tr>
<tr>
<td>Total volatile solids (TVS)</td>
</tr>
<tr>
<td>Chlorophyll a</td>
</tr>
<tr>
<td>Carotenoid</td>
</tr>
<tr>
<td>Ammoniacal nitrogen (AN)</td>
</tr>
<tr>
<td>Nitrate</td>
</tr>
<tr>
<td>Nitrite</td>
</tr>
<tr>
<td>Orthophosphate</td>
</tr>
</tbody>
</table>

Note: Units in mg litre\(^{-1}\) except pH
Closed PBR is increasingly used to grow microalgae for biofuel production due to water, energy and chemical savings as well as cost reduction. Most closed PBRs are designed as tubular reactors, plate reactors or bubble column reactors (Figure 1). Mixing is necessary in all these PBRs to prevent sedimentation of cells and support distribution of CO₂ and O₂.

**PERFORMANCE OF MICROALGAE CULTIVATION IN POME**

Upscaling microalgae cultivation using closed PBR is dependent on lipid content, growth rate and cell size. The lipid productivity is critical for microalgae to be used as a biodiesel feedstock. A high lipid content may improve the processing efficiency of biomass into biofuels (Rodolfi et al., 2009). *Chlorella vulgaris* UMACC 001 was cultivated in 5% POME in 250-ml flasks for 12 days. The flasks were incubated under controlled environment at 25±1°C, illuminated with cool white fluorescent lamp (40 µmol photon m⁻² s⁻¹) on 12:12-h light-dark cycle and supplied with 100 ml filtered ambient air and then transferred to an enclosed PBR at a laboratory for another six days. It was then transferred to an outdoor enclosed PBR for 12 days using Bold’s Basal Medium (BBM) as a control.

*Table 2* shows the growth of *Chlorella vulgaris* UMACC 001 in different culture system (Idris et al., 2017). The maximum optical density (OD₆₂₀) / cell size in BBM culture using annular PBR was in the range of 1.57-1.64 while the culture in 5% POME showed maximum OD₆₂₀ of 1.45 in an annular PBR and 1.81 in a flat panel PBR. Flat panel PBR yielded better OD₆₂₀ at outdoor condition in medium enriched with POME due to exposure of more sunlight leading to more biomass accumulation at an earlier stage compared to annular PBR. This was evidenced by higher biomass content (1.00±0.00 g litre⁻¹), specific growth rate (0.39 day⁻¹) and biomass productivity (0.14±0.00 g litre⁻¹ day⁻¹).

**Biodiesel Production from Microalgae**

Microalgal oil can be converted into biodiesel via transesterification. The fuel quality (i.e. cetane number, exhaust emission, heat of combustion, cold flow, oxidative stability, viscosity and lubricity) of the biodiesel derived depends very much on the fatty acid composition (chain length and number of double bonds or unsaturation, and chain branching) of the microalgal oil used (Schenk et al., 2008). The biodiesel quality can be further improved by adequate mixing of different microalgae feedstocks with oils having desirable fatty acids, or with genetically modified microalgal oil.
Ideally, a good biodiesel feedstock helps balancing the oxidative stability and the cold flow characteristics of the resulting biofuels (Schenk et al., 2008). *Chlorella vulgaris* UMACC 001 showed predominantly C16:0 and C18:1 fatty acids quite similar to palm oil. The balanced saturation (48%) versus unsaturation (51.1%) level, although not able to provide an ideal solution, shows biodiesel fuel properties comparable with studies by Velasquez-Orta et al. (2012), Johnson and Wen (2009) and Ehimen et al. (2010).

**BENEFITS**

An integrated POME treatment and microalgae cultivation may provide a sustainable way to conserve the environment. Utilisation of POME will increase the cultivation viability of microalgae as shown by other studies where a positive energy balance is possible in an integrated energy system consisting of POME anaerobic digestion, biomass power generation and microalgae cultivation (Abdullah et al., 2007; Abdullah et al., 2017). Microalgae-based biofuel is more promising compared to other bioenergy feedstock in terms of land area used. Moreover, advances in PBR engineering for microalgae cultivation will further lower the cost of biofuel production.

**CONCLUSION**

*Chlorella vulgaris* UMACC 001 is most productive when cultured in 5% POME using PBR at outdoor conditions. The algal oil assembles that of palm oil with an almost equal amount of saturated and unsaturated fatty acids dominated by C16 and C18. Thus, *Chlorella vulgaris* can be a potential biodiesel feedstock.

**TABLE 2. CHARACTERISTICS OF CHLORELLA VULGARIS UMACC 001 CULTURED IN PHOTOBIOREACTORS (PBRs) IN LABORATORY AND OUTDOOR CONDITIONS IN BOLD’S BASAL MEDIUM (BBM) AND 5% PALM OIL MILL EFFLUENT (POME)**

<table>
<thead>
<tr>
<th>System</th>
<th>Condition</th>
<th>OD&lt;sub&gt;620&lt;/sub&gt;</th>
<th>Biomass content (g litre&lt;sup&gt;-1&lt;/sup&gt;) (dwb)</th>
<th>Specific growth rate (day&lt;sup&gt;-1&lt;/sup&gt;)</th>
<th>Biomass productivity g litre day&lt;sup&gt;-1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annular PBR</td>
<td>Laboratory (BBM)</td>
<td>1.64±0.02</td>
<td>0.70±0.08</td>
<td>0.29</td>
<td>0.12±0.02</td>
</tr>
<tr>
<td>Annular PBR</td>
<td>Outdoor (BBM)</td>
<td>1.57±0.03</td>
<td>0.65±0.05</td>
<td>0.19</td>
<td>0.05±0.02</td>
</tr>
<tr>
<td>Annular PBR</td>
<td>Outdoor (5% POME)</td>
<td>1.45±0.00</td>
<td>0.80±0.00</td>
<td>0.19</td>
<td>0.11±0.00</td>
</tr>
<tr>
<td>Flat panel PBR</td>
<td>Outdoor (5% POME)</td>
<td>1.81±0.00</td>
<td>1.00±0.00</td>
<td>0.39</td>
<td>0.14±0.00</td>
</tr>
</tbody>
</table>

**REFERENCES**


Kushairi, A; Loh, S K; Azman, I; Elina, H; Meilina, O A; Zanal-Bidin, M N I; Razmah, G; Shamala, S and Ahmad-Parveez, G K (2018). Oil palm economic performance in Malaysia and R&D progress in 2017 – review article. J. Oil Palm Res.


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- Hardness
- Silica
- Phosphorus
- Chloride
- etc

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  - etc

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Sealing: Mechanical Seal

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Nursyairah Jalil*; Harrison Lau Lik Nang*; Rusnani Abdul Majid*; Ropandi Mamat*; Daryl Jay Thardeus*; Yung Chee Liang*; Wan Hasamudin Wan Hassan*; Yahaya Hawari*; Noraida Omar*; Astimar Abd Aziz* and Muhammad Alif Muhamad Noor**

INTRODUCTION

The Kuala Lumpur City Hall (DBKL), an agency under the Ministry of Federal Territories has been involved in the National Biodiesel Programme since February 2009. The first collaboration on biodiesel fuel between the Malaysian Palm Oil Board (MPOB) and DBKL was to use B5 diesel for the whole DBKL diesel fleet. B5 is a blend of 5% palm biodiesel with 95% petroleum diesel. The successful implementation of the B5 project with DBKL has supported the government to implement B5 program nationwide in phases for transportation and other subsidised sectors beginning in 2011. To further increase the biodiesel blending ratio in diesel, the government had then upgraded B5 to B7 programme since January 2015. So far, no technical complaints were received.

With the successful implementation of B5 and B7 programme, MPOB has initiated B10 project (a blend of 10% palm biodiesel with 90% petroleum diesel) with DBKL starting in February 2014. The project involved 50 units of DBKL diesel vehicles with various brands and applications including Nissan, Komatsu, Isuzu, JCB, TCM, Ford, Mazda, Toyota, Hicom, Kia, Volvo, Weststar, Case, etc. The manufacturing years of vehicles and machineries involved in the testing were ranging from 2000 to 2013. The brands and types of vehicles and machineries in DBKL B10 Project are listed in Table 1. Selected images of some vehicles and machineries used are shown in Figure 1.

As of July 2018, a total of 375, 520 liters of B10 had been used with total mileage accumulation of 1.7 million km for normal vehicles and 6200 hours for machinery

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** Kuala Lumpur City Hall (DBKL)
Km 4, Jalan Cheras
56100 Kuala Lumpur
TABLE 1. BREAKDOWN OF BRANDS AND TYPES OF VEHICLES AND MACHINERIES IN DBKL B10 PROJECT

<table>
<thead>
<tr>
<th>Brand</th>
<th>Application</th>
<th>No. of Machinery</th>
<th>Engine Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case</td>
<td>Excavator and backhoe</td>
<td>1</td>
<td>Italy</td>
</tr>
<tr>
<td>Komatsu</td>
<td>Tractor shovel</td>
<td>1</td>
<td>Japan</td>
</tr>
<tr>
<td>Hitachi</td>
<td>Excavator</td>
<td>1</td>
<td>Japan</td>
</tr>
<tr>
<td>JCB</td>
<td>Excavator and backhoe</td>
<td>2</td>
<td>UK</td>
</tr>
</tbody>
</table>

Total of Machinery 5

<table>
<thead>
<tr>
<th>Brand</th>
<th>Application</th>
<th>No. of Vehicle</th>
<th>Engine Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>HICOM</td>
<td>Vehicle carrier</td>
<td>2</td>
<td>Malaysia</td>
</tr>
<tr>
<td></td>
<td>Flatbottom lorry, 2.5 t with taillift</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Hino</td>
<td>Flatbottom lorry with taillift</td>
<td>1</td>
<td>Japan</td>
</tr>
<tr>
<td></td>
<td>Tipper, end with high side</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Patching lorry</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tipper, end with high side</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tipper, 3 way 5 t</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tipper, end 5 t</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Nissan</td>
<td>Aerial platform</td>
<td>2</td>
<td>Japan</td>
</tr>
<tr>
<td></td>
<td>Water tanker</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pick-up truck</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pick-up truck with crew cab</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flatbottom lorry 3 t with taillift</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flatbottom lorry with taillift</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tipper, 3 way 5 t</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tipper, end 5 t with crane</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Isuzu</td>
<td>Water tanker</td>
<td>1</td>
<td>Japan</td>
</tr>
<tr>
<td></td>
<td>Pick-up truck with crew cab</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Ford</td>
<td>Pick-up truck with crew cab</td>
<td>2</td>
<td>USA</td>
</tr>
<tr>
<td>Toyota</td>
<td>Pick-up truck</td>
<td>1</td>
<td>Japan</td>
</tr>
<tr>
<td>Mazda</td>
<td>Pick-up truck with crew cab</td>
<td>1</td>
<td>Japan</td>
</tr>
<tr>
<td>Kia</td>
<td>Van</td>
<td>1</td>
<td>Korea</td>
</tr>
<tr>
<td>Weststar</td>
<td>OKU Van</td>
<td>1</td>
<td>China</td>
</tr>
</tbody>
</table>

Total of Vehicle 45

Grant total 50

operation. So far, no technical issues have been reported due to the use of B10 diesel.

VISUAL INSPECTION OF FUEL FILTERS AND LUBRICATING OIL PERFORMANCE

Monitoring on the fuel filters and lubricating oil indicated that the operation of the B10-fuelled vehicles was the same as that of normal diesel and the replacement of fuel filter and lube oil was in accordance with normal service and maintenance schedule. Lubricating oil was collected during normal oil change interval of each vehicle by using extraction vacuum pump (Figure 2). Sample was taken after running engine for at least 15 min to ensure homogeneity. Analysis of fresh and used engine oil were conducted by ALS Technichem (M) Sdn. Bhd. Based on the laboratory results, all lubricating oil samples showed no unusual engine wear.
Engine assessment was conducted for two selected vehicles, *i.e.* Nissan UD truck LKA211N and Nissan Navara. The objective of engine assessment was to check the condition of the engine after using B10 including fuel system and other parts that were in direct contact with the fuel. Considering the problem-free operation of the two selected vehicles, *i.e.* Nissan UD truck LKA211N with Euro2 engine (WPA9372 – 130,000km) and Nissan Navara with Euro3 common rail engine (WXK 3673 – 90,000km), the dealers (representing Original Equipment Manufacturers – OEM) decided that the overhaul of these vehicles will only be carried out when they reach the recommended mileages (LKA211N – 150,000 km and Navara – 100,000 km). Following the standard procedure, overhauling should only be carried out when the vehicle has a problem. While waiting for these vehicles to achieve recommended mileages, compression test and injector diagnostic test were conducted for Nissan LKA211N and Nissan Navara at dedicated Nissan service workshop. The exhaust emission test was

### Engine Assessment

- Excavator Hitachi ZX210W-3
- Pick-up Truck Nissan Navara
- Water tanker Nissan LKA211N
- Tractor Shovel, wheeled Komatsu WA200-5

*Figure 1. Some of the vehicles and machineries using B10 diesel.*

*Figure 2. Extraction vacuum pump for lube oil sampling*

and no fuel dilution. All samples tested were within the acceptable limits. Example of certificate of results from a third party laboratory is shown in *Figure 3.*

The fuel filter collected was cut open for checking of any abnormality, and was found in normal condition as compared to fuel filter using B7 diesel. The replacement of fuel filter was done during normal service schedule, following standard procedure by manufacturers.
carried out for both the vehicles.

1) Injector Diagnostic Test

Diagnostic test on injectors for Nissan Navara (WXK 3673) was carried out at Tan Chong & Sons Motor Company Sdn Bhd workshop located at Batu Caves, Selangor (Figure 5). The results showed that the injectors were in normal working conditions using B10 diesel for 60 000 km.

2) Engine Compression Test

Engine compression test for Nissan UD truck LKA211N (WPA9372) was carried out at Tan Chong Industrial Equipment (TCIE) workshop located at Batu Caves, Selangor (Figure 6). It was found that compression pressures for six engine cylinders of Nissan UD truck LKA211N were ranged from 31 kgf cm$^{-2}$ to 32 kgf cm$^{-2}$ within the standard specification of 35 kgf cm$^{-2}$ as stated in engine manual. No excessive wear
and tear were found using B10 diesel for 100,000 km.

3) Tail-pipe Emission Test

Smoke test (Figure 7) for Nissan Navara at 60,000 km and Nissan UD LKA211N at 100,000 km was conducted by Department of Environment (DOE). The results of the exhaust and smoke emissions test for Nissan Navara and Nissan UD LKA211N were 2.7% and 2.8% respectively, which were below the maximum opacity limit of 50% set by the DOE. The tailpipe exhaust emission quality for the vehicles using B10 diesel has been greatly improved due to cleaner combustion of the fuel resulted in less smoke and unburnt hydrocarbon.
Driver Survey

Survey questionnaires have been given to all drivers to gather the experience of using B10. From the survey, it was noted that the drivers agreed that the engine performance of using B10 was comparable with engine running using normal diesel. In fact, majority of the drivers experienced better engine performance, better fuel consumption, smoother engine operation and more power when using B10 as shown in Figure 8.

CONCLUSION

The technical evaluation on vehicles using the B10 fuel for 4.5 years showed that the use of B10 will not cause any problem to the engine and operational issues. B10 diesel will not affect daily operation and maintenance cost of a vehicle as compared to the B7 diesel.
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Crude Palm Oil De-Chlorination

Andrew Yap Kian Chung*

ABSTRACT

High concentrations of 3-monochloro-1,2-propanediol (3-MCPD) were found in refined, bleached and deodorised (RBD) palm oil recently, implying that the level in edible oil consumption will exceed the tolerable daily intake (TDI) of 0.8 μg kg⁻¹ body weight as determined by the European Food Safety Authority (EFSA) (2016). A study showed that the reaction prerequisites for ester formation are the presence of fatty acids and ionic-bound chlorine. Although fatty acids neutralisation is an effective oil purification method, various technologies have been introduced to address the de-chlorination issue in crude palm oil so that the MCPD ester content in palm oil meets the European and the American market requirements which are currently below 2 mg kg⁻¹, and a further reduction to 0.5 ppm has been proposed.

Keywords: crude palm oil washing, de-chlorination, glycidyl esters, MCPD

INTRODUCTION

In the refinery, crude palm oil (CPO) containing organic chloride compounds has been bleached using bleaching earth containing free hydrogen chloride. The carcinogenic 3-monochloro-1,2-propanediol (3-MCPD) found in refined, bleached and deodorised (RBD) palm oil is formed in proportional to the fatty acids content in the oil during the deodorisation step carried out at 180°C-260°C in vegetable oil refining. Neutralisation of free fatty acids in palm oil with potassium salts prior to deodorisation can suppress the formation of 3-MCPD esters (Šmidrkal et al., 2016).

Formation kinetic models have been developed indicating that monopalmitin models show a linear dependence between 3-MCPD ester formation and chloride ion concentration (Hamlet et al., 2014).

The formation mechanism is complex (Bund für Lebensmittelrecht und Lebensmittelkunde E V ( BLL), 2016). A fatty acids-sodium chloride equilibrium is established with fatty acid salts and hydrogen chloride formation during deodorisation as shown in the reaction equation 1. Hydrogen chloride then reacts with acylglycerol as shown in Figure 1. Thus, the reaction prerequisites for 3-MCPD formation are the presence of fatty acids and ionic bound chlorine (Šmidrkal et al., 2016).

\[
\text{R}^\text{O} - \text{H} \leftrightarrow \text{R}^\text{O} - \text{H} + \text{Na}^+ \rightarrow \text{R}^\text{O} - \text{Na}^+ + \text{H}^+ \quad (1)
\]

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DE-CHLORINATION FOR 3-MCPD MITIGATION

The CPO sent to the refinery contains less than 5% free fatty acids based on the Palm Oil Refiners’ Association of Malaysia (PORAM) specifications, but chlorine content has yet to be determined at the moment. A survey found that refined palm oil contains many organic chlorine compounds and inorganic chlorides such as calcium chloride (CaCl₂), magnesium chloride (MgCl₂), ferum (II) chloride (FeCl₂) and ferum (III) chloride (FeCl₃) (Yu, 2014). The fertiliser, muriate of potash, used in oil palm plantations and the coagulant used for water treatment in palm oil mills are believed to be the sources of chloride. An unofficial survey found that the chloride content in crude palm oil generally ranges from 7 ppm to 11 ppm.

3-MCPD ester formation can be reduced by washing crude palm oil with water or ethanol (Musfirah et al., 2013). Alfa Laval (2016) proposed three focal points in palm oil processing at which 3-MCPD formation may be mitigated, namely zero dilution oil clarification, crude palm oil washing, and oil neutralisation.

Caustic soda has been widely used to produce neutralised palm olein or neutralised palm oil. The water-soluble fatty acid salts formed via saponification encapsulates proteins and other impurities. The duly neutralised oil will then be washed, and the wash water is usually removed using a disc stack centrifuge. Finally, the purified oil is dried in a vacuum dryer (Alfa Laval, 2016).

Figure 1. MCPD ester formation reaction.
Zero dilution oil clarification eliminates chlorine contamination from the dilution water added into the press liquor in a conventional mill. Thus, the crude oil is mixed only with water present in the fresh fruit, adsorbed water during sterilisation and from live steam heating. Hot water may also be added at the oil gutter under the press to facilitate press liquor drainage. A three-phase decanter with a nozzle disc stack separator can be used for oil recovery. Typically, 20% of the process water can be saved and the gravity settling tank can be omitted (Alfa Laval, 2016).

Crude palm oil washing can be carried out after the clarification process to reduce further the chlorine content in the pure oil before vacuum drying. Various systems have been tried or are still on trial. Issues that need to be considered are oil loss due to emulsion, wash water quality and quantity, additional load on the wastewater treatment plant, and additional operational expenditure (OPEX) and capital expenditure (CAPEX) incurred.

The Earth’s crust contains an average of 0.055% chlorine. The common soluble inorganic chloride compounds in industrial water supply are CaCl₂, MgCl₂ and sodium chloride (NaCl). Chlorine has been used in potable water treatment since the early 1900s although undesirable chlorinated by-products, such as trihalomethane, are formed in the presence of humic and fulvic acids (Cantafio, 1994). Malaysia’s raw drinking water should contain less than 250 mg litre⁻¹ chlorides (Ministry of Health Malaysia, 2000), while the average free chlorine residual in tap water should be 0.75 mg litre⁻¹ but varies from 0.3 mg litre⁻¹ to 2.10 mg litre⁻¹. The taste and odour threshold concentrations are 5 mg litre⁻¹ and 2 mg litre⁻¹, respectively (Ong et al., 2007).

Chlorine solubility at a temperature of 20°C and a pressure of 1 atm is 7.29 g litre⁻¹ in water as shown in the reaction equation 2 (Cantafio, 1994).

In alkaline conditions:
\[ \text{Cl}_2 + \text{H}_2\text{O} \leftrightarrow \text{HOCl} + \text{HCl} \]  \hspace{1cm} (2)
\[ \text{HOCl} \leftrightarrow \text{OCl}^- + \text{H}^+ \]

Medium-pressure UV de-chlorination is a proven technology involving photochemical reactions produced by UV light wavelengths between 180 nm and 400 nm. The peak wavelengths for free chlorine dissociation range from 180 nm to 200 nm, whereas the peak wavelengths for chloramines dissociation range from 245 nm to 365 nm. The UV dosage required depends on the total chlorine level, ratio of free versus combined chlorine, background organics level and concentration reduction target (McClean, 2007).

**DISCUSSION**

Vegetable oil and fat refiners are committed to reducing the level of glycidyl esters in all oils to 1 ppm (Fediol, 2016). In order to mitigate the issue of 3-MCPD ester in RBD palm oil, specifications for chlorine content in crude palm oil need to be established. In line with this, a rapid and simple method for determining chlorine content in oil is needed to support studies and surveys. A total halogens micro-coulometric combustion analyser has been introduced for this facility in the Trace Elemental Instruments laboratory. Samples are introduced into a furnace with an appropriate module for high temperature oxidation. The combustion gas with halide ions which is produced is fed into a sulphuric acid scrubber for rapid water and interference removal. The dried and clean gas is then led into a temperature-controlled titration cell with silver ions for the halide ion reaction. The halogen content in the sample is determined by the amount of charge used to regenerate the silver ions as shown in the reaction equation 3 (Trace Elemental Instruments, 2016). Table 1 shows the halogens content in different types of palm oil as determined by Metrohm Combustion IC.

**CONCLUSION**

A palm oil yield of 6 t⁻¹ ha yr⁻¹ can be achieved, which is the highest oil yield among the commercial oilseed crops. Unfortunately, a
recent survey found that the 3-MCPD level in RBD palm oil is the highest among the edible oils in the market. Studies show that the ester issue can be mitigated by neutralisation with potassium salts and de-chlorination of the crude palm oil prior to oil refining. Free fatty acids neutralisation and de-chlorination efforts need to be considered whether as a refining process modification or as a step integrated into palm oil milling.

REFERENCEs


Musfirah, Z; Oi, M L; Soo, C T; Razam, A L and Chin, P T (2013). Optimisation of palm oil physical refining process for reduction of 3-monochloropane-1,2-diol (3-MCPD) ester formation. J. Agricultural and Food Chemistry; 61: 3341-3349.


Table 1. Halogens Content in Different Types of Palm Oil

<table>
<thead>
<tr>
<th></th>
<th>Chlorine [mg kg⁻¹]</th>
<th>Sulphur [mg kg⁻¹]</th>
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<tr>
<td>Crude palm oil</td>
<td>7.5</td>
<td>4.1</td>
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<tr>
<td>Washed palm oil</td>
<td>3.1</td>
<td>2.7</td>
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<td>Refined palm oil</td>
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<td>1.5</td>
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The Inventor’s Dilemma

P. Kandiah*

A tricky issue that has long plagued inventors and researchers who invent potentially commercially useful products or processes is the dilemma as to whether to:

i) Seek patent rights for the invention,

ii) Keep the details of the invention confidential (or as a trade secret), or

iii) Publish the details of the invention and depend on copyright protection afforded by the Copyright Act. The publication could be in a peer review journal, or as a paper presented at a conference proceeding.

So the question is, which path to take? That’s the dilemma. Let’s look at the various options available and the implications of each path to the inventor/researcher.

Where the research is undertaken in an academic institution or in a research institution, there is a culture of publishing the details of the invention in a peer review journal or as a paper presented at a reputable conference. In fact, in many institutions, it is a policy or internal regulation, requiring all research output in the institution to be published as early as possible. Academics are still governed by the ‘publish or perish’ rule.

The publication, whether in a journal or in conference proceedings would nevertheless enjoy copyright protection, unless expressly disclaimed. But is copyright protection of the publication sufficient to protect the inventor’s interests or is it sufficient to prevent any other person from taking advantage of the invention disclosed in the publication by using the invention for commercial gain?

Copyright merely allows the owner (who could be the inventor, or the institution where the inventor is employed to do research) to prevent any others from substantial reproduction of the published works, but does not grant any right to prevent others from making use of the teachings or the details disclosed in the publication. For example, assume A publishes an article or a book entitled ‘The Art of Making Furniture’ where modern methods of making furniture are disclosed in detail. The publication (the book or the article) would enjoy copyright protection. What right does A have? Is copyright protection sufficient to protect A’s interests? If, say, a furniture manufacturer,
B, obtains a copy of the publication and follows the teachings in the publication to improve his manufacturing method or produce new types of furniture disclosed in the publication, there is nothing A can do to prevent B from using the teachings, or even to demand monetary compensation or royalty from B. A’s publication disclosing the details of his knowledge in making furniture will be deemed to be a donation to the public, allowing others to freely benefit from the creative or intellectual output. If A (or his employer) wanted to benefit financially from the creative efforts, then A (or his employer) has to claim proprietary rights to the invention by way of patent rights (on the assumption that the creative output is patentable).

Can copyright and patent rights be claimed for the invention? Or is a claim to copyright and a claim to patent mutually exclusive? Has it to be one or the other? The patent laws of all countries require that the features claimed in the patent should be novel as at the date of first filing of the patent application. So if the inventor has disclosed details of the invention to the public in any manner (e.g., by publishing details of the invention in a journal, on a website or even orally at a conference proceeding/seminar) prior to the filing of the patent application, the requirement of novelty is not met and a patent will not be granted, and if granted it can be invalidated for lacking in novelty. Even the inventor’s own publication (where the inventor is named as the author of the paper) is sufficient to destroy the novelty, and is no excuse. (Note: Some countries do excuse such prior publications by the inventor, provided the patent application is filed within a stipulated period (called the grace period).

It is advisable not to rely on the grace period as an excuse to publish the invention before filing the patent application. However, it is possible to file the patent application and thereafter, on the very next day, publish the details of the invention, although for strategic reasons it is not advisable to do so, especially if further research is still being carried out in the subject matter of the invention. The author has personal experience where a granted patent for a commercially important invention is being challenged by a competitor for lack of novelty citing the inventor’s own publication of the invention in his institution’s in-house publications and on the institution’s website.

Alternatively, can the inventor keep the invention confidential or as a trade secret instead of filing a patent or publishing the invention and claiming copyright? If the invention relates to a chemical product or a method of manufacture, details of which can be kept confidential within the four walls of the factory and which product or process cannot be reverse engineered within the four walls of the factory and which product or process cannot be reverse engineered by analysis of the product which is placed in the market, then it may be advantageous to keep the details of the product or process of manufacture as a trade secret. However in this modern age of availability of sophisticated analytical tools and techniques, I doubt if such a process or composition can be kept confidential and cannot be reverse engineered. Reverse engineering a product or process is lawful although it may not be morally acceptable or ethical. Further, once the trade secret is leaked, there is no way the secret can be put back into the bottle. It is also difficult to take legal action against anyone accused of using stolen trade secrets or of obtaining trade secrets unlawfully. If the inventor is desirous of commercialising his invention, then potential investors or licensees would demand to see patent rights and would not be favourable to obtaining a licence to use trade secrets.

In summary, it can be concluded that where an inventor is researching an area with potentially high commercial value, he is strongly advised to seek patent rights for the invention (assuming the results of the research meet the patentability criteria) rather than depend on copyright protection or trade secret.
Caution: This area of practice of intellectual property rights is complex and highly technical in nature. Inventors are strongly advised to seek professional advice from experienced practitioners in the field. This article is published purely for information and should not be construed as legal advice. Each case would depend on its own facts as to determine the best way to claim proprietary rights in order to commercialise the invention.

P. Kandiah is the Founder and Director of KASS International, an established intellectual property firm with offices in Malaysia, Singapore, Indonesia and Myanmar. Mr. Kandiah has vast experience in obtaining patents, trademarks and industrial design rights on a global scale, and also specializes in identifying patentable inventions, designing around patented technology, and advising on the commercialization of IP Rights, franchising and licensing strategies. For more information, visit www.kass.asia or drop an e-mail to kass@kass.asia
A series of complaints were made by the public claiming that palm oil mills in Johor discharge effluents from their mills into the waterways, and thus contributed to pollution of ammonia in the nearby rivers. Previously, one of the water treatment plants in Johor failed to produce fresh water for domestic and household use due to high level of ammonia at the plant’s water intake point. Even though it was later verified that the effluents from the mills were not the primary source of pollution of ammonia in the rivers, it was observed that several violations of environmental regulation by the mills such as overflow of effluent and improper effluent management, have sent a signal to the public that the palm oil mills were the culprit. Consequently, the authority has enforced a stringent limit for the quality of palm oil mill effluent (POME) discharged at sensitive area, particularly for mills located at the upstream river.

In tandem with MPOB’s aim towards promoting sustainable palm oil, a taskforce has been initiated to address and monitor closely regulatory issues of the environment for palm oil mills. Earlier in February 2018, the taskforce has visited the affected mills in Johor as preparative work prior to conducting the intensive study. Thereafter, a field study of two weeks was planned at three palm oil mills located in Kluang district, namely KKS Lawiang, KKS Coronation, and KKS Ulu Sebol.

The purpose of this study was to investigate the effectiveness of effluent treatment system of each mill through daily sampling of untreated, semi-treated and treated effluent at different points within...
the treatment system. On-site measurement was also conducted for pH, temperature and dissolved oxygen at various effluent ponds. Besides that, the team also reviewed the mill’s previous records which included milling activity, effluent treatment and effluent testing. Upstream and downstream locations of adjacent watercourse were also identified. Figure 1 depicts the points of sampling which enabled the team to fully understand the effectiveness of the palm oil mill effluent system.

Planning of simultaneous study is important and requires proper arrangement which involves manpower, relevant scope of study, budgeting, communication with personnel of palm oil mills and laboratory for effluent testing. Other objectives of this study are to investigate the corrective actions taken by the mill to improve the treatment system due to previous complaints, as well as to determine the effectiveness of the treatment system to fulfill the environmental requirements. The selected mills were previously compounded by Department of Environment due to various offences; hence, they are required to rectify the identified problems, such as desludging, digging additional ponds and using enzymes to accelerate rectification.

This study demonstrates continuous commitment of MPOB to address environmental issues related to palm oil mills. It is also expected that the outcome of this study will be able to clarify issues associated with ammonia pollution and create awareness on the sustainability of palm oil mills.

Figure 2. Illustration of the scope of study conducted at the effluent treatment system of palm oil mill.

Figure 3. Daily sampling and on-site measurement of relevant parameters at early stage of treatment (cooling / anaerobic ponds) conducted by MPOB researchers.

Figure 4. Samples are prepared, bottled and stored according to the standard sampling method.

Figure 5. Analysis of upstream and downstream rivers were also included in the scope of study due to complaint on ammonia pollution.
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Engineering and Processing Division
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☐ Bearings/belts/pulleys  ☐ Fluid control system/couplings  ☐ Renewable energy
☐ Bio-compost/biomass/bio-products  ☐ Gaskets/packing materials/seals  ☐ Screw press/parts
☐ Boiler spares/control/others  ☐ Gear boxes/geared motors  ☐ Scrubbers/biogas
☐ Boiler suppliers and related services  ☐ Hardware (M.S. pipes, M.S plates, etc.)  ☐ Sludge separators/decanters
☐ Boiler suppliers  ☐ Heat exchanger  ☐ Steam turbines/generators/spares
☐ Bunch crushers  ☐ Hydraulic systems/services/spares  ☐ Steriliser/ports
☐ Castings/fabrication work/welding  ☐ Laboratory analysis/chemicals  ☐ Storage tanks/silos/vessels etc.
☐ Civil engineering works  ☐ Laboratory fittings and furniture  ☐ Vacuum pumps/dryer etc.
☐ Cleaning - general/sand dashing  ☐ Laboratory equipment/fittings etc.  ☐ Valves/seats etc.
☐ Condition monitoring services  ☐ Lubricants (food grade/hydro carbon)  ☐ Vibrators [Industrial]/related equipment
☐ Consultancy services/certification  ☐ Meters/flow/thermos/pressure gauge  ☐ Water treatment
☐ Control systems/automation/spares  ☐ Mill machinery/spares  ☐ Waste water treatment/services
☐ Conveyors/chains/elevators/belts etc.  ☐ Miscellaneous  ☐ Weighing machines/spares
☐ Dust collectors  ☐ Nut crackers  ☐ Welding equipments/spares
☐ Diesel engines/spares/services  ☐ Oil recovery systems  ☐ Wheel loaders/spares
☐ Dynamic balancing  ☐ Palm kernel oil crushing plant
☐ Edible oil processing system  ☐ Plate heat exchanger
☐ Electric motors/electrical systems  ☐ Pollution control/safety systems
☐ Expansion joints/insulations  ☐ Power plant and related equipment
☐ Fabrication/casting/welding  ☐ Pressure vacuum vessels/tanks

Signature: ____________________________
Name: ________________________________
Date: ________________________________

(Company Stamp)
FEEDBACK FORM

From: 
Address: 

Question/Comment: 

Signed: 
Date: 

(We have enclosed this form to assist you in sending to us any questions or comment, alternatively please email your feedback to rohaya@mpob.gov.my)
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Palm Oil Engineering Bulletin
Malaysian Palm Oil Board
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43000 Kajang, Selangor,
Malaysia
Most Environmental Friendly Way to produce Ultra-Pure Water (UPW) using High Efficiency Deionized Purification System (HEDPS)

- Smallest and patented vessels
- 50% Space saving
- Small amount of powder resin
- 90% saving in Volume
- Less acid and caustic consumption
- 50% saving in acid regenerants & caustic regenerants
- Less water displacement for rinsing
- 33% saving in water usage
- Fully automated and less manpower to operate
- No close monitoring during regeneration

Effective Sludge Removal using MULTI-DISK SCREW PRESS (MDS)

Features:
- Fully Stainless Steel
- Enclosed to minimize odors and noise
- Very low wash water usage (1/8 compared with belt press)
- Very low power consumption (1/20 compared with centrifuge)
- High cake solids
- Minimal operator requirement
- Easy to operate and maintain
- Auto start-up, run and shutdown
- Touch screen operation (optional)

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Tilting Sterilizer
The Best Solution In Sterilization System
PATENT NUMBER (MY-139899-A)

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Patent Number (MY-139899-A)
ALL NEW PHYSICAL REFINING 2018
- Smart Refining
- Nutrient Enhancement Refining
- Ultra Low Color Refining
- 3-MCPD and GE Mitigation
- Zero Waste Water Discharge

INTEGRATED & MULTI-FEEDSTOCK BIODIESEL PLANT
- Low Utility Consumption
- Highest Methyl Ester Conversion and Product Yield
- Highest Methyl Ester Quality In Compliance to International Biodiesel Standards
- EN14214, ASTM D6751 and MS2008
- Improved Cold Seal Filtration
- Recovery of Phytonutrients

PKO FRACTIONATION
- Tray Type Process Provides Consistent and Homogeneous Cooling
- High Product Quality and Consistent Yield
- Highly Selectivity for Specialty Fats and Customized Quality Products
- Clean, Reliable and Safe Operation
- Optimum CAPEX with Minimum Maintenance Requirement

POME BIOGAS CAPTURE PLANT
- CSTR with Contact Process for Optimal Anaerobic Digestion Efficiency
- High Efficiency Methane Recovery
- Optimum CAPEX over Long Term with Low OPEX Cost
- Minimum Service with Zero Down Time - No Desludging Needed

TEXTURIZING LINE
- (Shortening / Margarine / Specialty Fats, etc.)
- High Flexibility and Easy Operation for Various Products
- Clean, Dry and Quiet Environment
- Sanitary Standard
- Reliable System with Highest Safety Features
- Optimum CAPEX with Minimum OPEX

PATENTED HYBRID CRYSTALLIZER
- Olein from IV56-83 with Single Fractionation
- Olein from IV65 and above with Double Fractionation
- Stearin Fractionation and Spray Chamber
- PMF and Specialty Fats

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