Can High Biodiesel Blends Be Used in Cold Highlands Environment?

Nursyairah Jalil[1*]; Harrison Lau Lik Nang[1] and Rifqi Irzuan Abdul Jalal[2]
[1] Malaysian Palm Oil Board (MPOB), 6, Persiaran Institusi, Bandar Baru Bangi, 43000 Kajang, Selangor, Malaysia.
[2] Taylor's University, 1, Jalan Taylors, 47500 Subang Jaya, Selangor, Malaysia.
*E-mail: nursyairah@mpob.gov.my

INTRODUCTION

The use of biodiesel in compression ignition engines has attracted global attention as it alleviates global warming concerning the environment. Nevertheless, its low temperature flow characteristic remains a major challenge when used as a substitute for petroleum diesel in cold places such as highlands and areas with moderate temperatures. The use of biodiesel blends could possibly cause fuel starvation and operational issues at low temperatures as solidified materials could clog fuel lines and filters due to their high content of saturated components (Joshi and Pegg, 2007). Cold temperatures lead to a decrease in fuel viscosity, and resulted in engine fuel supply and performance issues (Dwivedi and Sharma, 2014). These issues are more prominent in biodiesel deriving from oils with high content of saturated fatty acids (Hoekman and Robbins, 2012). Biodiesel tends to precipitate when exposed to cold temperatures in the presence of unreacted saturated monoglycerides that could lead to filter clogging and injectors choking (Dwivedi and Sharma, 2013).

In order to protect end users, Malaysia has restricted the use of biodiesel blends up to B7 (7% palm biodiesel with 93% petroleum diesel) in three highlands, namely Cameron Highlands, Genting Highlands and Kundasang, while other areas are using B10/B20 (10% or 20% palm biodiesel with 90% or 80% petroleum diesel).

BIODEISEL BEHAVIOUR IN COLD TEMPERATURE

The composition of fatty acid in oils plays a crucial role in influencing the physicochemical characteristics of biodiesel. For instance, the presence of high saturated fatty acids significantly impacts properties such as cetane number, cold filter plugging point (CFPP), kinematic viscosity, density, cloud point (CP) and pour point (PP). Properties of biodiesel can vary substantially from one feedstock to another due to differences in their chemical compositions. Palm oil contains 32%-47% palmitic acid which is categoried as long-chain saturated fatty acid. Their presence in palm oil feedstock give good oxidative stability and less NOx emissions. Nevertheless, it will result in poor cold flow properties which might be unsuitable in cold climate conditions (Lanjekar and Deshmukh, 2016). *Figure 1* compares the fatty acids composition of common vegetable oils as biodiesel feedstock.

Cold flow characteristics refer to the performance of fuels at low temperatures which are determined by CP, CFPP and PP. The higher the saturated fatty acids content of biodiesel feedstock, the higher the CP and PP values (Lanjekar and Deshmukh, 2016). Thus, palm biodiesel may potentially experience low-temperature operability issues, especially in cold areas such as highlands.

Neat palm biodiesel has higher CP and PP compared to petroleum diesel (Nursyairah *et al.*, 2022). Exposure of the fuel to temperatures at or below CP for an extended period causes crystals to grow and forms interlocking networks, leading to fuel starvation and interruptions in fuel flow (Kumar *et al.*, 2016). Nevertheless, CFPP is commonly used to assess low-temperature operability of a fuel and predict the lowest temperature at which it will flow freely through fuel filters in a diesel engine (Zöldy, 2019).

Two types of commercial diesel blends are offered in the market, known as B7 and B10/B20. B7 is sold at selected petrol stations as protection grade for diesel vehicles that cannot use high biodiesel blends while B10 is available nationwide. B20 is only available at Langkawi, Labuan and Sarawak (except Bintulu). Starting April 2021, the Euro 2M petroleum diesel used to blend with palm biodiesel was replaced by Euro 5 diesel. *Figure 2* shows that CFPP of Euro 5 blends are always lower than Euro 2M blends. Based on these CFPP values, we foresee that up to B20 of Euro 2M and up to B30 of Euro 5 can be used in highlands since their CFPP are way lower than 10.9°C, the lowest temperature recorded so far in those areas (Nursyairah *et al.,* 2021).

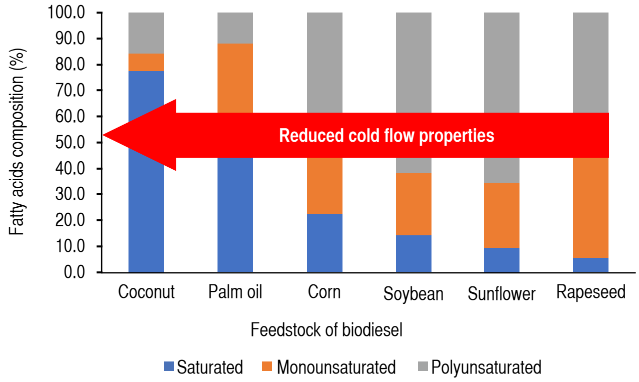

Figure 1. Fatty acids profile of common vegetable oils for the production of biodiesel.

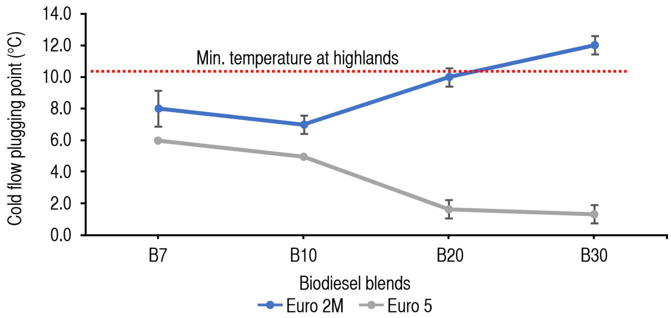

Figure 2. Cold flow plugging point of palm biodiesel blends in Malaysia.

VEHICLE COLD TESTING USING BIODIESEL BLENDS FUEL

Climatic cold testing laboratory facilities at Proton and National Emission Test Centre, Rawang, as well as actual testing at Cameron Highlands were conducted on three types of diesel vehicles commonly found in Cameron Highlands as in *Table 1*. The diesel vehicles ranged from old technology, featuring a mechanical inline injector pump diesel engine, to more advanced models equipped with turbocharged common rail diesel engines. Biodiesel blended with Euro 2M was used for Vehicle 1, while Vehicles 2 and 3 were fueled with Euro 5 biodiesel blends.

TABLE 1. DIESEL VEHICLES FOR COLD TESTING USING BIODIESEL BLENDS

	Vehicle 1	Vehicle 2	Vehicle 3
Vehicle type	Toyota Fortuner	Toyota Hilux	Mitsubishi Pajero
			
Engine type	Direct-injection diesel engine	Direct-injection diesel engine	4D56 engine Intercooled Turbo (TD04 Turbo)
Fuel system	Common Rail	Common Rail	Distribution type jet pump
Test fuel	Euro 2M B7, B10, B20 and B30	Euro 5 B7, B10, B20 and B30	
Climatic chamber	PROTON, Shah Alam	National Emission Test Centre, Rawang	

LABORATORY TEST

Laboratory test in cold chamber simulated the average climatic conditions expected in Malaysia highlands by continuously exposing the vehicle to ambient cold temperatures for 6.5 hr without any fluctuations, replicating day and night environmental conditions. Four temperatures (20°C, 15°C, 10°C and 5°C) and eight biodiesel blends (Euro 2M and Euro 5M: B7, B10, B20 and B30) were used to analyse the performance of these diesel vehicles. The complete vehicle was attached on the chassis dynamometer in a climatic chamber with temperature control from -40°C to 30°C (*Figure 3*).

Cold start performance was tested using CEC M-11-T-91 method. Startability was defined as the ability of the vehicle to start with standard starting procedures. Vehicle using Euro 2M B20 could start at 15°C, but failed at 10°C (*Figure 4*). Vehicle using B30 can only start at ≥20°C. In contrast, vehicles with Euro 5 biodiesel blends did not encounter any startability issues even at constant temperature as low as 5°C.

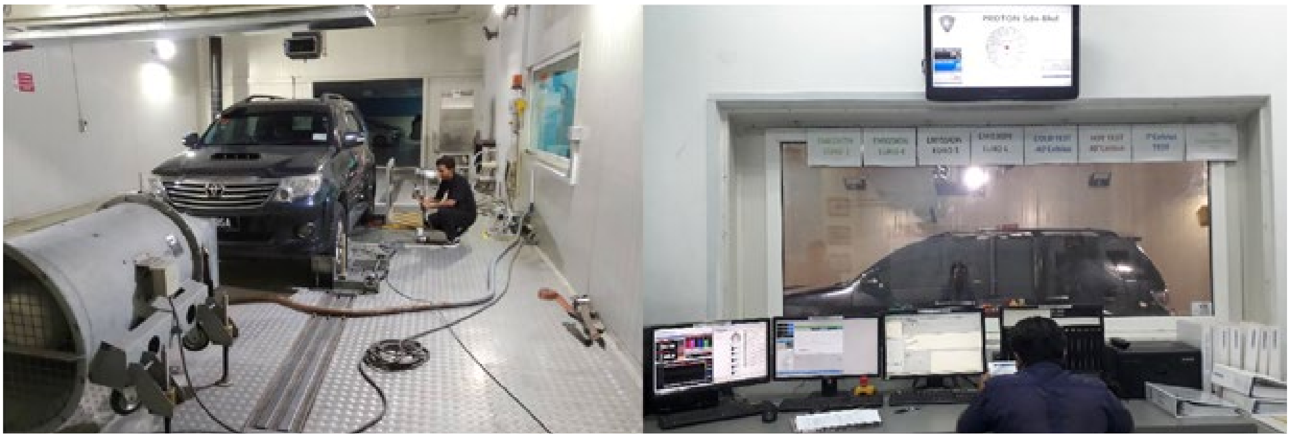

Figure 3. Test vehicle in climatic chamber at Proton Shah Alam, Selangor, Malaysia.

Euro 2M Biodiesel

	B7	B10	B20	B30
20°C	○	○	○	○
15°C	○	○	○	✗
10°C	○	○	✗	✗
5°C	✗	✗	✗	✗

Euro 5 Biodiesel

	B7	B10	B20	B30
20°C	○	○	○	○
15°C	○	○	○	○
10°C	○	○	○	○
5°C	○	○	○	○

○ Can start ✗ Fail to start

Figure 4. Startability of diesel vehicles using biodiesel blends.

ON-THE-ROAD TEST

On the road test is required at highlands to check on engine performance at actual environmental conditions, which fluctuate during day and night. The test was conducted at Cameron Highlands covering four different routes: (1) downhill driving, (2) idling, (3) uphill driving and (4) town driving (*Figure 5*) to ensure that all aspects of actual driving experience were simulated, with a total distance of 37.9 km per trip. The test route starts with a 500 m downhill stretch followed by a 5-minute idle period, then climbs back up before continuing through city driving and ending at the same starting location. This test route mimicked the common routine of pickup truck collecting vegetables and other goods in the morning for transporting to lower areas.

All vehicles involving in the test performed well with both biodiesel blends of up to B30 for Euro 2M and Euro 5 (*Figure 5*). Following the local driving behavior, *i.e.* commuting early in the morning (5.00-7.00 am) at average ambient temperature of 15.2°C, no issues were encountered during engine start-up, and the vehicles ran smoothly without any operational problems.

CONCLUSION

Climatic laboratory studies showed that biodiesel blends (Euro 2M) of up to B20 can withstand temperatures starting at 15°C, while B30 at 20°C. For Euro 5 biodiesel blends up to B30, no startability issues encountered during the test. On the other hand, for actual cold climate testing, on-the-road test revealed diesel vehicles using both Euro 2M and Euro 5 biodiesel blends up to B30 did not face any technical issues. In conclusion, biodiesel blends of up to B30 can be used in Malaysia's highlands environment without any operational issues.

Euro 2M Biodiesel **Euro 5 Biodiesel**

	B7	B10	B20	B30
20°C	○	○	○	○
15°C	○	○	○	○
10°C	○	○	○	○
5°C	○	○	○	○

○ can start ✗ Fail to start

Figure 5. Driveability of vehicles using biodiesel blends in Cameron Highlands.

REFERENCES

Dwivedi, G and Sharma, M P (2013). Cold flow behaviour of biodiesel - A review. *International Journal of Renewable Energy Research*, *3(4)*: 827-836.

Dwivedi, G and Sharma, M P (2014). Impact of cold flow properties of biodiesel on engine performance. *Renewable and Sustainable Energy Reviews*, *31*: 650-656. DOI: 10.1016/j.rser.2013.12.035.

Hoekman, S K and Robbins, C (2012). Review of the effects of biodiesel on NOx emissions. *Fuel Processing Technology*, *96*: 237-249. DOI: 10.1016/j.fuproc.2011.12.036.

Joshi, R M and Pegg, M J (2007). Flow properties of biodiesel fuel blends at low temperatures. *Fuel*, *86*: 143-151. DOI: 10.1016/j.fuel.2006.06.005.

Kumar, P; Sharma, M and Dwivedi, G (2016). Impact of ternary blends of biodiesel on diesel engine performance. *Egyptian Journal of Petroleum*, *25(2)*: 255-261. DOI: 10.1016/j.ejpe.2015.06.010.

Lanjekar, R D and Deshmukh, D (2016). A review of the effect of the composition of biodiesel on NOx emission, oxidative stability and cold flow properties. *Renewable and Sustainable Energy Reviews*, *54*: 1401-1411. DOI: 10.1016/j.rser.2015.10.034.

Nursyairah, J; Lau, H L N; Jalal, R I A and Loh, S K (2022). Effect of palm biodiesel blends on cold start performance and emissions of common rail turbocharged engine at moderately cold ambient temperatures. *Environmental Progress & Sustainable Energy*, *42(3)*: e14037. DOI: 10.1002/ep.14037.

Nursyairah, J; Lau, H L N and Jalal, R I A (2021). The cold flow properties on palm biodiesel for diesel blends mandate in Malaysia's highlands', *J. Oil Palm Res.*, *31(1)*: 116-128. DOI: 10.21894/jopr.2021.0027.

Zöldy, M (2019). Investigation of correlation between diesel fuel cold operability and standardized cold flow properties. *Periodica Polytechnica Transportation Engineering*, *49(2)*: 120-125. DOI: 10.3311/PPTR.14148.