# Real-World Vehicle Trials: A Look Into Palm Biodiesel and Other Feedstocks

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## INTRODUCTION

Biodiesel is a renewable fuel that can be produced from various feedstocks such as vegetable oils, animal fats and waste cooking oils (WCOs). Biodiesel is an environmentally friendly and sustainable alternative to conventional diesel, derived commonly through the transesterification process from oil of the chosen feedstock (Mosarof *et al.,* 2015). Biodiesel has been widely used in many countries as a blend with conventional diesel fuel to reduce the dependence on fossil fuels, as well as to lower the emissions of greenhouse gases and pollutants. However, the effects of biodiesel blends on real-world exhaust emissions and fuel consumption of diesel vehicles are not well understood and may vary depending on the biodiesel feedstock, blend ratio, vehicle type, engine technology and driving conditions. This article aims to summarize the prevailing knowledge base available regarding the usage of biodiesel blends in real-world studies in the form of vehicle trials.

## BIODIESEL BLENDS

Biodiesel blends are mixtures of biodiesel and conventional diesel fuel in different proportions. The most common available biodiesel blend ratios are B5 (5% biodiesel and 95% diesel), B20 (20% biodiesel and 80% diesel) and B100 (pure biodiesel). The properties of biodiesel blends depend on the actual properties of both the biodiesel and diesel components, which are influenced by the feedstock type, production process and quality standards. Generally, biodiesel has higher oxygen content, cetane number, viscosity, density, and flash point than diesel, but with lower heating value, volatility, and lubricity. The properties of biodiesel blends tend to change linearly with the blend ratio, except for some nonlinear effects such as cloud point, pour point and cold filter plugging point. The properties of biodiesel blends tend to affect engine performance, combustion characteristics and emission formation mechanisms.

Biodiesel blends are widely used worldwide as compared to the net form of biodiesel because of general acceptance by the vehicle manufacturers. The acceptable biodiesel blending ratio varies from country to country depending on government policy, typically ranging from 5% to 35%. The effects of biodiesel blends on the performance, emissions, durability, and maintenance of diesel engines and vehicles are of considerable importance to manufacturers. Given that vehicle manufacturers tailor their products for specific fuel use, they offer recommendations for acceptable fuel blends, where warranties typically cover 'materials and workmanship' (Lopes and Cushing, 2012).

## REAL-WORLD FUEL CONSUMPTION VEHICLE STUDIES USING BIODIESEL BLENDS

Real-world fuel consumption is the actual fuel consumption of vehicles measured under real driving conditions using an onboard fuel consumption meter (OFCM). Real-world fuel consumption may differ significantly from laboratory fuel consumption measured under standardised test cycles using chassis dynamometers or engine test benches. Stationary fuel consumption studies can have appropriate control over different factors such as vehicle type, engine technology, emission control system, fuel quality, driving behaviour, road conditions, traffic situations, ambient temperature, and humidity in a controlled environment. Conditions in the real world are more dynamic than in controlled environments, which can be useful as reliable data in fuel economy evaluation, life cycle assessment, and policy making.

The following studies shown in *Table 1* have been conducted to investigate the real-world fuel consumption of diesel vehicles fueled by biodiesel blends derived from various feedstocks. These studies represent the main vehicle types that use diesel on the road which are cars, trucks, and buses. The main methods used in these studies include onboard fuel consumption meters. The results of these studies are summarised in *Table 1*.

The examination of real-world vehicle trials reveals that biodiesel blends derived from waste cooking oils have varying impacts on the exhaust emissions and fuel consumption of diesel vehicles, contingent upon factors such as vehicle type, engine technology, emission control system, and driving conditions. The key findings can be succinctly summarised as follows:

- Biodiesel blends generally elevate the carbonyl emissions of diesel vehicles, particularly those equipped with particulate oxidation catalyst (POC) systems. The heightened carbonyl emissions may be ascribed to the increased oxygen content and reduced heating value of biodiesel, potentially intensifying the oxidation of fuel and lubricant and diminishing combustion efficiency. The impact of biodiesel blends on carbonyl emissions is also influenced by driving conditions, with higher emissions observed under heavy workload (HW) conditions compared to non-heavy workload (NHW) conditions. This correlation might be linked to the elevated engine load and temperature under HW conditions, potentially fostering the formation and oxidation of carbonyls (Cao *et al*., 2020).
- Biodiesel blends generally result in reduced emissions of carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and particulate matter (PM) in diesel vehicles, especially those equipped with selective catalytic reduction (SCR) systems. CO and HC are by-products of incomplete combustion, contributing to smog formation and respiratory issues. NOx and PM are major air pollutants associated with acid rain, ozone depletion, visibility impairment, and health damage. The diminished emissions of these pollutants can be attributed to the higher oxygen content and cetane number of biodiesel, potentially enhancing combustion quality and reducing soot and NOx formation. The effects of biodiesel blends on these emissions are also influenced by the driving cycle, with lower emissions observed during HW cycles compared to NHW cycles. This correlation may be associated with the higher engine speed and air-fuel ratio during HW cycles, potentially improving combustion efficiency and decreasing emission formation (Shen *et al.,* 2018).

Biodiesel blends may lead to increased fuel consumption in diesel vehicles, particularly when high

**TABLE 1. REAL-WORLD FUEL CONSUMPTION VEHICLE TRIAL STUDIES USING BIODIESEL BLENDS**

| Study | Feedstock | Blend ratio | Vehicle type | Engine technology | Emission control system | Main findings |
|---|---|---|---|---|---|---|
| 1 | Rapeseed oil | B0-B100 | Diesel cars | Euro III-VI | SCR/DOC/DPF/EGR | • Biodiesel increased fuel consumption for all vehicles;<br>• The increase in fuel consumption was proportional to the biodiesel content in the blend;<br>• The increase in fuel consumption was higher for newer vehicles with advanced emission control systems |
| 2 | Soybean oil | B0-B20 | Diesel buses | Euro III-VI | SCR/DOC/DPF/EGR | • Biodiesel had no significant effect on fuel consumption for most vehicles;<br>• Biodiesel slightly increased fuel consumption for some vehicles with SCR systems;<br>• The effect of biodiesel on fuel consumption was different for various driving cycles and emission standards |
| 3 | Palm oil | B0-B20 | Diesel trucks | Euro III-VI | SCR/DOC/DPF/EGR | • Biodiesel slightly decreased fuel consumption for some vehicles with SCR systems;<br>• Biodiesel slightly increased fuel consumption for some vehicles with DOC/DPF/EGR systems;<br>• The effect of biodiesel on fuel consumption was not significant for most vehicles |

blends such as B30 is used. Fuel consumption serves as a crucial indicator of energy efficiency and greenhouse gas emissions. The elevated fuel consumption may be attributed to the lower heating value and increased density of biodiesel, potentially reducing energy output, and increasing fuel mass per unit volume. The impact of biodiesel blends on fuel consumption is also influenced by emission standards, with newer vehicles exhibiting lower fuel consumption compared to older vehicles.

## REAL-WORLD ENGINE LUBRICATING OIL QUALITY VEHICLE TRIAL STUDIES USING BIODIESEL BLENDS

Lubricating oil (LO) for diesel engines plays a crucial role in functions such as friction reduction, cooling, cleaning, sealing, and safeguarding engine components. However, the quality and effectiveness of LO may degrade over time due to factors like oxidation, contamination, dilution, and degradation. The use of biodiesel blends as alternative fuels for diesel engines is one factor that could impact the quality and performance of LO. LO properties can influence combustion characteristics, emission formation mechanisms, and fuel-lubricant interactions in diesel engines. Therefore, understanding the impact of biodiesel blends on LO quality and performance in real-world conditions is crucial.

Real-world trial studies, conducted through fleet tests, provide a more accurate representation of the effects of biodiesel blends on LO quality and performance compared to laboratory tests or simulation models. The primary factors affecting engine LO condition in these studies are the type of fuel used and the frequency of service intervals.

Numerous studies have explored the influence of biodiesel blends on LO quality and performance in diesel vehicles under real-world conditions through field tests or fleet tests. The key parameters measured in these studies include viscosity, total base number (TBN), total acid number (TAN), oxidation stability, water content, ash content, metal content, and wear rate. Viscosity, TBN, TAN, and oxidation stability are particularly relevant physical properties of engine LO, which can be used as a measure of its performance limits. On the other hand, water content, ash content, metal content, and wear rate help assess the effects of contaminants from external or internal sources on engine LO, ultimately altering its physical properties.

The effects of biodiesel blends on LO are contingent upon factors such as vehicle type, engine technology, emission control systems, and driving conditions. The key findings are summarised as follows:

- Biodiesel blends generally result in reduced viscosity, increased TAN, and reduced oxidation stability of LO. Viscosity, a measure of LO's resistance to flow, impacts its lubricating and cooling capabilities for engine parts. TAN reflects the acidity of LO, indicating its degradation due to oxidation. Oxidation stability gauges LO's resistance to oxidation, influencing its service life. The reduced viscosity, increased TAN, and reduced oxidation stability are attributed to the higher oxygen content and lower heating value of biodiesel, which enhance LO oxidation, and reduce volatility. Driving conditions also influence these parameters, with higher values observed under HW conditions compared to NHW conditions. This correlation may be linked to the increased engine load and temperature under HW conditions, accelerating the oxidation rate and viscosity index of LO. (Gulzar *et al.,* 2016; Awang *et al.,* 2022)
- Biodiesel blends generally lead to a decrease in the TBN and water content of LO. TBN measures LO's alkalinity, indicating its ability to neutralise acidic compounds produced by oxidation. Water content affects LO's lubricity and corrosion resistance. The reduced TBN and water content are attributed to the higher polarity and hygroscopicity of biodiesel, increasing the solubility and absorption of water and acidic compounds in LO. Like the viscosity-related parameters, driving conditions also influence TBN and water content, with lower values observed under HW conditions compared to NHW conditions. This correlation may be associated with the higher engine speed and air-fuel ratio under HW conditions, promoting the evaporation and combustion of water and acidic compounds in LO. (Gulzar *et al.,* 2016; Awang *et al.,* 2022)
- Biodiesel blends generally exhibit no significant impact on the ash and metal contents of LO. Ash content measures inorganic residues in LO, affecting its cleanliness and filterability. Metal content indicates contamination and wear levels. The lack of significant effects on these parameters may be attributed to the similar composition and quality of biodiesel and diesel components, suggesting comparable sources and levels of inorganic and metal contaminants.

Vehicle type, engine technology, and emission control systems also play a role in influencing these parameters, resulting in different values for vehicles with distinct technologies and systems. (Gulzar *et al.,* 2016; Awang *et al.,* 2022)

- Biodiesel blends has no significant impact on the wear rate of engine parts. Wear rate, measuring material loss due to friction and wear between engine parts, impacts their durability and reliability. For some cases, the heightened wear rate is attributed to the lower lubricity and higher viscosity of biodiesel, which reduce the formation of a protective oil film, and increase friction force between engine parts.

## CONCLUSION

Real-world vehicle trials are a great source of actual data on the usage of biodiesel blends. With the increasing importance of switching to alternative fuels to offset pollution and dependence on fossil fuels, reliable data on biodiesel usage is crucial for fleet companies to consider. Fuel consumption with biodiesel blends needs to be determined as the perception that such alternative fuels would reduce vehicle efficiency remains. Vehicle trials also should analyse LO samples to discern trends from real-world data, showcasing vehicles operating within acceptable ranges in terms of LO mileage usability. This in turn would ensure optimum performance of vehicle by adopting suitable servicing and maintenance schedule when using alternative fuels such as high blend of biodiesel.

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