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COMPARISON OF EFFECT OF CONVENTIONAL FUEL WITH NEWLY DEVELOPED BIOFUEL IN OPERATION AND EMISSION CONDITIONS OF PISTON COMBUSTION ENGINE

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The present paper deals with the evaluation of the impact of newly developed biofuels together with a comparison with conventionally produced fuel, diesel, in terms of their impact on the technical and emission condition of a studied vehicle. The main energy and emission parameters of the internal combustion diesel engine were evaluated. For laboratory experiments, a discrete test method was used for comprehensive assessment, the procedure of which is described in the methodology of the paper together with a description of the measurement chain designed to achieve the determined results. The paper deals with the evaluation of the measured results of power, torque, consumption, and emissions such as CO_2 and absorption coefficient. Among the technical parameters, the power and torque drop were observed for each biofuel. The decrease is attributed to lower values of calorific value, viscosity, and density. A positive effect was observed for the CO_2 and absorption coefficient emission parameters, i.e., a decrease for each of the newly developed biofuels studied.

Keywords: dynamometer; performance parameters; specific fuel consumption; absorption coefficient, CO_2

With mounting evidence of the health effects of diesel particulates, concerns about emissions have grown significantly. Ideally, diesel fuel is a mixture of hydrocarbons which, when oxidised, produces CO_2 and water vapour (H_2O). Actual combustion is far from ideal and produces many by-products (Reif, 2014). Currently, more than half of the road transport fleet uses diesel engines, which are often identified as the primary source of air pollution (Pourdarbani et al., 2022). The measurement of exhaust emissions produced by the internal combustion piston engine is monitored and regulated significantly during road vehicles' driving and approval tests. Particular attention has recently been paid to the amount of CO_2 emissions (Procházka et al., 2022). The introduction of the EURO 7 standard is intended to accelerate the transition to sustainable mobility and bring Europe closer to achieving the 2050 climate neutrality target (Xie et al., 2020). Stricter vehicle emission standards better protect the environment and human health. One way to achieve better environmental protection is through the use of alternative fuels produced from renewable energy sources. There are different approaches to the effort to reduce the environmental impact of transportation and agricultural machinery operation such as alternative fuels, electric vehicles, improved combustion engines, or improving their technical condition (Čedík et al., 2018). Road transport is increasing all around the globe, and biofuels have come to the forefront of public interest (Kotek et al., 2019). Renewable energy is a promising alternative to fossil fuels because it is clean and environmentally friendly. According to European Renewable Energy Council, almost half of global energy demand will come from renewables in 2040. It also states that the most promising renewable energy source is biomass (Ramesh, 2021). Biofuels and bioproducts made from plant biomass mitigate global warming because the CO_2 released during combustion is equal to the CO_2 bound by plants during photosynthesis, and thus CO_2 levels are not increased in the atmosphere (Stevens and Verhé, 2004). Biodiesel is biodegradable and non-toxic, has low emission profiles, and is therefore beneficial to the environment. Environmental issues are the strongest motivation for increasing biodiesel production and consumption. Oil consumption is peaking every year, and this trend is set to continue for at least 10–15 years. As a result, high oil consumption leads to local air pollution and global warming problems caused by CO_2. The main disadvantages of vegetable oils as diesel fuel are higher viscosity, lower volatility, and the reactivity of unsaturated hydrocarbon chains. Biodiesel generates slightly less energy and consumes more fuel compared to diesel (Omidvarborna et al., 2014). Some types of biofuels can have a negative impact due to the economic and environmental costs associated with the refining process and the potential removal or replacement of large areas of arable land that is used for growing and producing food (Chaudhury and Hashmi, 2020). On the other hand, biofuels lead to gradual independence from oil, while on the international market, crude oil price is seen as very sensitive to various world events such as war, invasion, financial conditions, international policies, technological advancements, identification of new oil reserves, the price of other competing energy resources, and other geopolitical issues (Sharma and Shrestha, 2023). Also, biodiesel-fuelled diesel engines have lower emissions

of carbon monoxide, unburned hydrocarbons, particulate matter, and air toxins than when run on petroleum-based diesel (Omidvarborna et al., 2014; Hajjari et al., 2017). Biodiesel is also safer compared to conventionally produced diesel, is non-toxic (about 10 times less toxic than table salt), and has a higher flash point than conventional diesel. In addition, B100 (clean biofuel) can reduce CO_2 emissions by up to 78% and reduce the carcinogenic properties of diesel by 94% (National Biodiesel Board, US DOE Office of Transportation Technologies) (Earthroamer, 2019). In this paper, we evaluate undeveloped fuels and their impact on the technical and emission parameters of an internal combustion engine compared to a conventionally produced fuel.

The results from the presented article could contribute to the creation of more ecological and efficient alternative fuels, which would minimise the negative impact on the technical condition of the vehicle and at the same time contribute to the reduction of greenhouse gas emissions. The results can be used to further improve the environmental properties of new biofuels and strengthen their ability to reduce CO_2 emissions.

Material and methods

The object of investigation of the impact of newly developed biofuels is a vehicle Peugeot 208, which has a 1.4 eHDi diesel internal combustion engine with a displacement of 1.397 cm^3 and meets the EU5 emission class. Power, torque, and consumption measurements were carried out on the above vehicle by means of a MAHA MSR 500/2 CAR 4WD cylinder brake. By adding the MET 6.3 mobile emission station equipment, the individual emission values (CO, CO_2, HC, NO_x, absorption coefficient) were recorded. The basic parameters of the vehicle are given in Table 1.

During the experiment, the influence of the reference fuel and newly developed fuels on the technical and emission condition of the diesel internal combustion engine were monitored and compared. The reference fuel and the measured values of selected parameters established by the methodology of the work for the purpose of comparison with individual biofuels is petroleum diesel fuel designated with the letter "D", which must meet the parameters and properties prescribed. The basic characteristics, parameters, and test methods based on EN 590:2022 are given in Table 2.

The characteristics of newly developed biofuels for monitoring the impact on the emission and technical condition of the diesel internal combustion engine together with the test methods according to EN 14214:2019 are given in Table 3.

The MSR 500/2 CAR 4WD cylindrical dynamometer was used for individual laboratory experiments. It is used for dynamic and static power measurements at test speeds up to 300 $km \cdot h^{-1}$. The MSR 500/2 CAR 4WD guarantees an optimum accuracy and reproducibility of measurement by actively measuring the pulling power (Fig. 1). The rolling properties of the tyre are the same as on the road. Operational methods such as load simulation are possible, including optional modules for measuring external data such as driving cycles. A single-cylinder, all-wheel drive dynamometer for vehicles with axle loads up to 2.4 t, incorporating an eddy current brake and an electric motor per set of cylinders, is suitable

Table 1 Basic characteristics of Peugeot 208

Peugeot 208	
Internal combustion engine specification	1.4 eHDi
Engine type	diesel
Engine designation	8HP
Maximum engine power kW/rpm	50 kW/4000 rpm
Maximum torque Nm/rpm	160 Nm/1750 rpm
Engine capacity	1.397 cm^3
Number of cylinders	4
Maximum speed	163
Maximum acceleration (0–100 $km \cdot h^{-1}$)	13.5 s
Supercharging	yes
Gearbox type	automatic
Number of gears	5
Emission class	EU5
Fuel type	oil
Average consumption – city	4.5 $l \cdot 100\ km^{-1}$
Average consumption – outside the city	3.5 $l \cdot 100\ km^{-1}$
Combined average consumption	3.8 $l \cdot 100\ km^{-1}$
Tyres	185/65 R15

Table 2 Reference fuel with specification "D"

Parameter	Unit	Test method	Limit		Value
			Min.	Max.	
Density at 15 °C	$kg \cdot m^{-3}$	ISO 3675:2007	820	845	820.3
Cetane number	-	ISO 5165:2020	51	–	52.7
Cetane index	-	ISO 4264:2018	46	–	53.4
Sulphur content	$mg \cdot kg^{-1}$	ISO 20846:2019		10	0.9
Flash point	°C	ISO 2719:2016	55	–	57
Carbon residues	% ($m \cdot m^{-1}$)	ISO 10370:2014	–	0.30	<0.30
Water content	$mg \cdot kg^{-1}$	ISO 12937:2000	–	200	63
Total contamination	$mg \cdot kg^{-1}$	EN 12662:2014	–	24	5.2
FAME content	% (v/v)	EN 14078:2014	–	7	0.0
Oxidation stability	$g \cdot m^{-3}$	ISO 12205:1995	–	25	3
Lubrication	Mm	ISO 12152-1:2012	–	460	421
Viscosity at 40 °C	$mm^2 \cdot s^{-1}$	ISO 3104:2023	2	4.50	2.46
Distillation at 250 °C	% ($v \cdot v^{-1}$)	ISO 3405:2019	–	65	51
Distillation at 350 °C	% ($v \cdot v^{-1}$)		85	–	99
95% (v·v-1) distillation	°C		–	360	341.8
Heating value	$MJ \cdot kg^{-1}$	ASTM D5865-07	–	–	47.21

Table 3 Basic characteristics of selected properties of used biofuels

Parameter	Unit	Test method	Limit		Biofuel	
			Min.	Max.	B1	B2
Density at 15 °C	$kg \cdot m^{-3}$	ISO 3675:2007	860	900	870.2	873.0
Ester content	% ($m \cdot m^{-1}$)	EN 14103:2020	>96.5	97.09	96.9	
Flash point	°C	ISO 2719:2016	>101	145	148	
Carbon residues	% ($m \cdot m^{-1}$)	ISO 10370:2014	<0.30	0.15	0.24	
Viscosity at 40 °C	$mm^2 \cdot s^{-1}$	ASTM D6751	3.50	5.00	4.10	4.29
Water content	$mg \cdot kg^{-1}$	ISO 12937:2000	<500	341	399	
Total contamination	$mg \cdot kg^{-1}$	EN 12662:2014	<24	1.7	3.1	
Linolenic acid methyl ester	% ($m \cdot m^{-1}$)	EN 14103:2020	<12	7.62	3.25	
Heating value	$MJ \cdot kg^{-1}$	ASTM D5865-07	-	-	44.92	44.12

for performance measurement, tuning, and diagnostic work in very high-performance vehicles (MAHA, 2022).

In order to achieve the specified objectives, it is necessary to define the main parameters of the monitored object, the selection of the appropriate measurement chain to achieve relevant results. The methodology for the implementation of laboratory measurements consists of the following activities:

Preparation of the vehicle and measuring equipment:

- Peugeot 208, suitably and securely fixed at four points on the MAHA MSR 500/2 4WD dynamometer.
- Connecting the AIC 5000 consumption meter to vehicle's fuel system circuit, venting the system .
- Connecting the exhaust gas temperature sensor to the exhaust line termination.
- Connecting the sampling probe of the MET 6.3 emission gas analyser. The probe was placed in the exhaust pipe in accordance with the methodology for measuring the emission condition of motor vehicles.
- Exhaust gas extraction installations.
- Connecting the dynamometer module to the vehicle diagnostic socket.
- Deactivating the electronic stabilisation system (ESP).

Preparation for measurement:

- Setting the input parameters in the dynamometer program (the type of test, time of power measurement, sensitivity of automatic recognition of the run-in test, delay for recording the power loss, speed at which the measurement is started and the run-in test ends, load simulation profile, setting of vehicle parameters, speed index of tyres, fuel density).

Roller diameter	504 mm / 20"
Rolling circumference	1583 mm
Roller length	750 mm
Track width (min....max.)	700...2200 mm
Roller wall thickness	12 mm
Total weight of Roller set	4130 kg
Mech. inertia weight	2 x 280 kg
Permissible axle load	2500 kg
Maximum speed	300 km/h
Maximum speed of a tracked, non-driven axle	approx. 200 km/h
Motor power	2 x 22 kW
Wheel power Front axle stat. / dyn.	260 / 1000 kW (Peak)
Wheel power Rear axle stat. / dyn.	260 / 1000 kW (Peak)
Tractive force Front axle	approx. 7000 N
Tractive force Front axle	approx. 7000 N
Fuse	63 A
Supply voltage	3 x 400 + N + PE



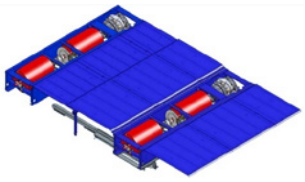


Fig. 1 Technical parameters of the dynamometer MAHA MSR 500/2 CAR 4WD
Source: Manualslib, 2023

Measurement principle	Volumetric, oscillating piston, with microprocessor controlled pulse emitter (Pat.AIC)
Measuring range	AIC 5004: 1 to 120 l/h
	AIC 5008: 4 to 240 l/h
Accuracy	Better than 1%
Repeatability	Better than 0.2 %
Admissible pressure	-1 to 6 bar
Mounting position	Horisontal
Operating temperature	-30.....90 C°
Ingress protection	Sensor, IP 67



Fig. 2 Technical characteristics of AIC 5000 Flow Master
Source: AIC Systems AG, 2023

Measurement properties						
Measured variables	Measuring range	Measurement accuracy	Principle of measurement	Resolution	Response time (T90)	Gas running time
HC (hexane)	0 to 2 000 ppm	±4 ppm abs. or 3% rel.	NDIR	1 ppm vol	3.5 s	2.8 s
HC (propane)	0 to 4 000 ppm	±8 ppm abs. or 3% rel.				
	4 001 to 10 000 ppm	±5% rel.				
	10 001 to 30 000 ppm	±10% rel.				
CO	0.00 to 10.00 vol. %	±0.02% abs. or ±3% rel.		0.01 vol. %		
	10.00 to 15.00 vol. %	±5% rel.				
CO_2	0.00 to 16.00 vol. %	±0.3% abs. or ±3% rel.				
	16.01 to 20.00 vol. %	±5% rel.				
O_2	0.00 to 25.00	±0.02% abs. or 1% rel.	Electro-chemical	0.01 vol. %	5 s	3.3 s
Lambda	0 to 9.999		Brettschneider calculation	0.001		
Opacity coefficient	0 to 9.99 m^{-1}		Extinction measurement	0.01 m^{-1}	Mode A 0.05 s Mode B 1 s	1.8 s
Opacity	0 to 99%			0.1%		
Particle mass concentration	1 to 1 100 mg/m^3			1 mg/m^3		
Engine temp.	0 to 150 °C			1 °C		
Speed	400 to 8 000 rpm			1 rpm		



Fig. 3 Technical parameters of the exhaust gas analyser for measuring vehicles with petrol and diesel engines MET 6.3
Source: MAHA, 2023

– Warming up the vehicle to operating temperature.
– Measuring the technical condition of the diesel internal combustion engine (power, torque, consumption) using a discrete method.
– Carrying out the individual measurements of emission condition of the diesel internal combustion engine on the test vehicle with the reference sample and newly developed biofuels.
– After each series of experiments, replacing the fuel filter.

The AIC 5000 fuel consumption measurement system (Fig. 2) was used to measure the consumption of the vehicle. The unit integrates a powerful fuel pump and a high-efficiency heat exchanger to condition the temperature of the hotter diesel returning from the internal combustion engine, thereby reproducing engine thermodynamics as in real conditions. The AIC's direct measurement technology provides accuracy better than +/-1%. The device works on the principle of rotary piston technology, which is suitable as a method of measuring fuel consumption. The moving piston oscillates gently in the measuring chamber and is protected by a thin film of fuel, thus achieving low levels of mechanical friction and wear rates. The measuring principle consists of extracting the fuel from the tank, the volume of which is measured by the AIC flow meter. Thanks to this solution, no fuel is returned to the tank, but passes through the volumetric measuring chamber, which represents an accurate, instantaneous consumption of the diesel internal combustion engine to 3 decimal places (AIC Systems AG, 2023).

The emission of the diesel internal combustion engine was monitored by the mobile exhaust gas analyser MET 6.3 from MAHA, which is designed for vehicles with spark-ignition and diesel engines (Fig. 3). It is characterised by a short warm-up time and fast readiness for measurement. It allows measuring petrol and diesel engines via one probe and to analyse their gaseous components HC, CO, CO_2, NO_x, and O_2 with lambda probe calculation. The device also allows the diagnosis of opacity, *K*-value, and particle

concentration using the partial flow method under free acceleration or with the engine under load. The meter operates with an expanded measurement uncertainty *U* expressed as standard measurement uncertainty multiplied by the overlap factor $k = 2$, which corresponds to a coverage probability of approximately 95% with normal distribution. Uncertainty was determined according to MSA 0104 and EA-4/02 M:2022 to be 97% and 97%, respectively.

To determine the correction factor K_a for the measured parameters, the absolute temperature *T* of the air drawn into the engine (expressed in *K*) and dry atmospheric pressure *p* (expressed in kPa or mbar) were measured. Then, the parameter K_a was determined according to the relations given below. For compression-ignition internal combustion engines without supercharging or with mechanical supercharging, the relations according to the DIN, EWG, ISO, SAE, and JIS standards were used to determine the correction factor. For the standards EWG 80/1269, SAE J1349, and JIS D1001: 1993, the calculation of the correction factor applies according to the relationship (MAHA, 2022):

$$K_a = \left[\left(\frac{990}{p} \right)^{0.7} \cdot \left(\frac{T}{298} \right)^{1.5} \right]^{-fm} \quad (1)$$

For the DIN 70020:2013 standard, Eq. (2) applies:

$$K_a = \frac{1013}{p} \cdot \left(\frac{T}{293} \right)^{0.5} \quad (2)$$

For ISO 1585:2020, Eq. (3) applies:

$$K_a = \left[\left(\frac{990}{p} \right)^{0.7} \cdot \left(\frac{T}{298} \right)^{1.2} \right]^{-fm} \quad (3)$$

where: K_a – the correction factor; *p* – atmospheric pressure (mbar); *T* – air temperature at the test bench (K); f_m – engine factor

The measurement of the selected parameters was carried out through the discrete method. The difference between the continuous and discrete methods of performance measurement is in the specification of the minimum and maximum speed, vehicle speed, and the number of steps in which the measurement is carried out for a prescribed period of time. In the discrete measurement, the step value of 16 km·h^{-1} was set, resulting in the set initial speed of 50 km·h^{-1} and up to the final speed of 6 measurement points at which the subsequent measurements of the monitored parameters were performed. The settling time was set at 30 seconds. This time took into account the stabilisation of the internal combustion engine as well as the time required for recording and evaluating emissions with the MAHA MET 6.3 measuring device and the AIC 5000 fuel consumption meter. This type of test was chosen as an alternative to continuous measurement in order to investigate its potential suitability for measuring the technical and emission parameters of the diesel internal combustion engine. Continuous measurement introduces the possibility of biased results due to transients in the diesel internal combustion engine. There may also be distorted results due to insufficiently fast response of sensors. With discrete measurement, the transients in the diesel internal combustion engine are stabilised at the measurement points, which allows more realistic operating results to be obtained. It is also possible to eliminate the negative effect of a phenomenon called "turbo-lag", which is associated with turbocharged engines. This phenomenon occurs because the turbine has inertia, and it takes a certain amount of time for turbo blades to spin up to their maximum speed after the throttle is added. The phenomenon also occurs at lower engine speeds when the turbo fails to develop the maximum pressure, which can take up to several seconds.

Results and discussion

For the discrete measurement, the vehicle had to be accelerated to the first measurement point (initial speed given by the operator) at 50 km·h^{-1} during the test. Subsequently, the software of the measuring device started the first recording of the monitored parameters for a set period of 10 s. This was followed by run-up to the second measurement point at 66 km·h^{-1}, at which the recording of the monitored parameters was repeated for a set period of time. The same procedure was followed for the other measurement points with a step of 16 km·h^{-1} at each measurement point. After the last set point at 142 km·h^{-1}, the roller brake program instructed the ramp to the final point at 150 km·h^{-1}, after which the catch-up test started. The vehicle operator was instructed by the roller brake program to decelerate. The discrete measurement ended with the vehicle coming to a complete stop. The diesel internal combustion engine parameters were tested with a reference sample (conventional diesel) and with alternative newly developed fuels, designated as B1 and B2. The results obtained were processed in the form of graphs. The tests were carried out at an average laboratory temperature of 25.7 °C, a pressure of 996.23 hPa, and a relative humidity of 52.3%. Average inlet air temperature was 23.7 °C, while the average temperature of the diesel internal combustion engine during the test was 90.4 °C.

In discrete measurement, the average power value was 56.77 kW at the speed of 3691 rpm. Among the biofuels, the highest power value of 53.15 kW was measured for the sample labelled B1 at the speed of 3690 rpm, which represented a -6.36% decrease in power compared to diesel. Biodiesel B2 showed a decrease of 7.34% with the maximum power value of 52.60 kW. The graphical power waveforms during the discrete measurement are shown in Fig. 4.

Biodiesel content and the biodiesel itself makes a difference in the performance of the diesel internal combustion engine. A decrease in engine performance was observed over the entire revolution range. In terms of biodiesel, fuel heating value and viscosity have an effect on performance reduction. The calorific value is an important measure of the release of energy required to produce work. Lower calorific value causes lower power output. Similarly, a higher viscosity of the biofuels used leads to loss in power due to the fact that higher viscosity reduces combustion efficiency due to a poor atomisation of the injected fuel. The graphical torque waveforms during the discrete measurement are shown in Fig. 5.

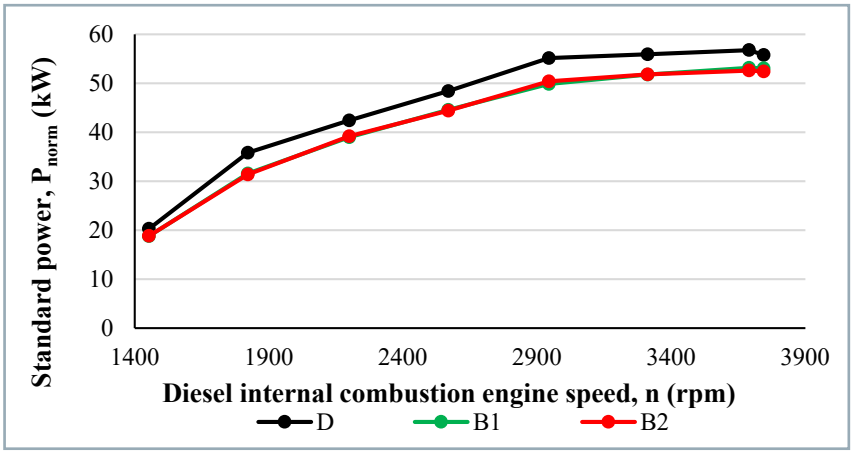


Fig. 4 Vehicle performance during the discrete measurements of individual biofuel and reference fuel samples

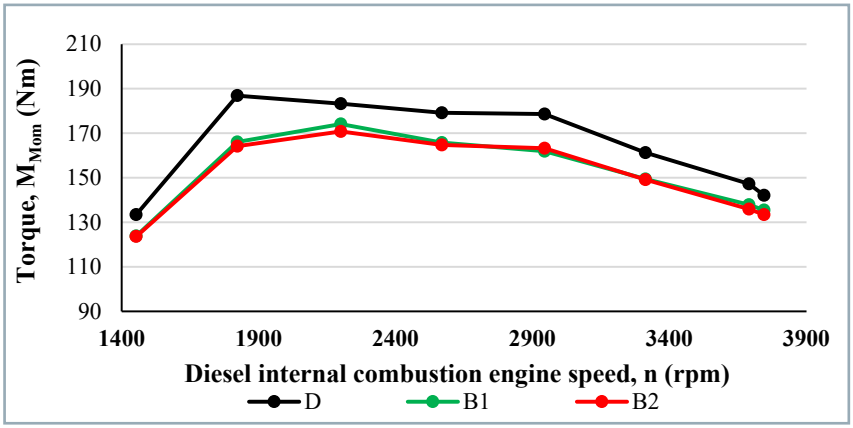


Fig. 5 Torque waveform of the vehicle during the discrete measurements of individual biofuel and reference fuel samples

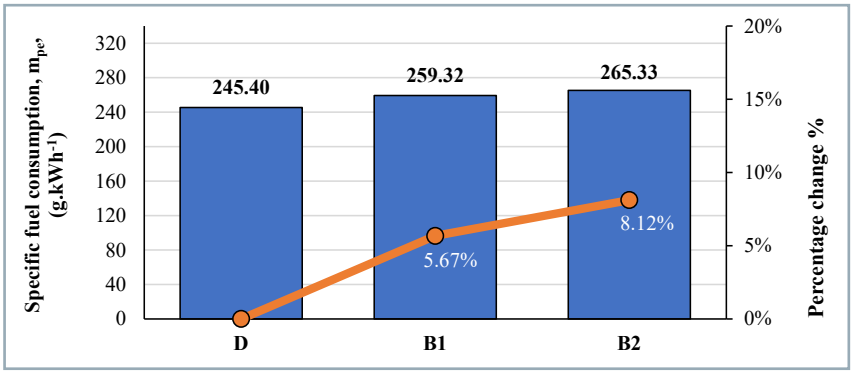


Fig. 6 Average values and percentage differences of the effective specific fuel consumption of the vehicle in each fuel sample during the discrete measurement

During the discrete measurement, the same ranking in terms of power drop was obtained. The highest average torque value was achieved by the reference fuel with a value of 186.90 Nm, at a speed of 1822 rpm. This was followed by the biofuel B1; its *Mk* level was 174.13 Nm at 2200 rpm with a decrease of 6.83%. At the same speed, the maximum values of biofuel B2 were obtained with 170.80 Nm and the drop of 8.62%.

As with performance, the properties such as biofuel type, viscosity, and calorific value are important in terms of the effect on torque. The negative impact of biofuel with respect to torque may be due to a higher viscosity of the biofuel used and lower calorific value. It can be concluded that the use of biodiesel samples leads to reduction in power and torque.

To evaluate the impact of biofuels on the economy of the studied diesel internal combustion engine, specific fuel consumption was monitored (Fig. 6). In the experiments with newly developed biofuels, higher consumption values were found for all the biofuels used with respect to the reference fuel, in both continuous and discrete measurements.

The reference fuel achieved an average specific consumption of 237.1 g·kW·h^{-1}. Higher percentage differences in consumption were found during the continuous measurement. For biofuel B1, an average consumption of 253.78 g·kW·h^{-1} was found, which represented a 7.03% increase. For fuel B2, a consumption value of 265.03 g·kW·h^{-1} was found with 11.77%. In the discrete measurement, biofuel B1 achieved an increase in consumption with respect to the reference fuel with 5.67%, biofuel B2 with an increase of 8.12%. The observed increase in fuel consumption driven by biodiesel may be due to the need to compensate for the loss of calorific value. Also, the density and viscosity of the biofuels used may have an effect on the observed increase, since a higher value causes more mass injection at the same injection volume and injection pressure. Another factor influencing the increased demand may be the feedstock used to produce the biodiesel, which may be reflected in the difference in the economy of the diesel internal combustion engine.

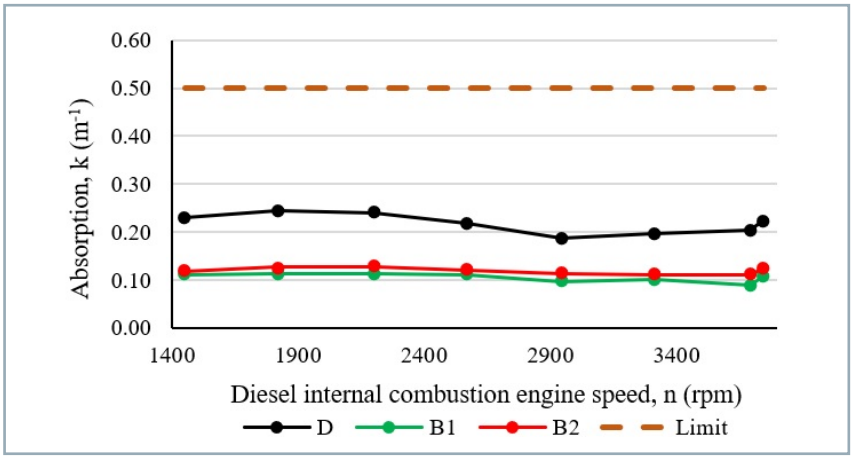


Fig. 7 Absorption coefficient during discrete measurements of individual biofuel and reference fuel samples

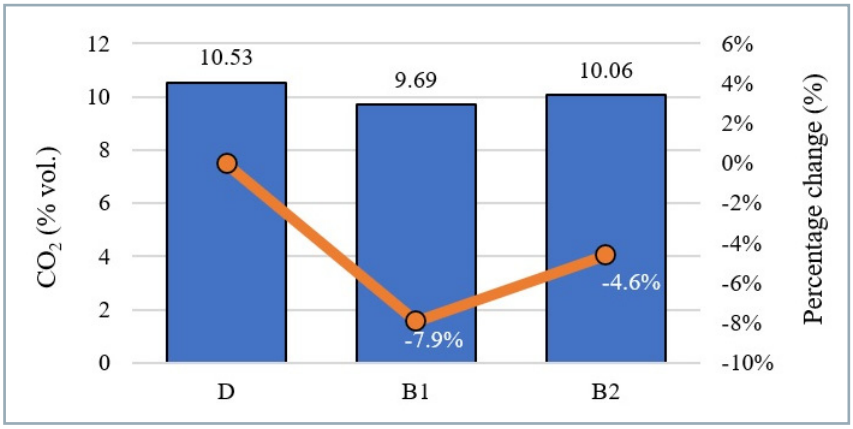


Fig. 8 Average values and percentage differences of the CO_2 emissions of the different fuel samples during the discrete measurement

In Fig. 7, the absorption coefficient traces of the individual samples of newly developed biofuels and their comparison with the reference sample during the discrete measurement can be seen.

In discrete measurement, the transient states of a diesel internal combustion engine are steady-state. For absorption coefficient values during the individual measurements, a decrease in absorption coefficient was found for each biofuel sample studied. This is smoke opacity, which is defined as the amount of light hidden by particulate matter or soot particles emitted during the combustion of diesel fuel. Smoke opacity reflects the presence of soot in exhaust gases. It depends on the engine load, viscosity, and cetane number of the fuel. The main arguments for reducing the value of absorption coefficient are the higher content of bound oxygen, lower carbon-hydrogen ratio, the unavailability of aromatic compounds in biodiesel, and shorter ignition delay. The graph shows that the absorption coefficient values for all the fuel types tested are generally very low as the vehicle is fitted with a diesel particulate filter (DPF). The advantage of lower values of absorption coefficient and therefore of particulate matter is that soot components may result in a longer interval between two DPF regenerations or a longer technical life of the DPF when biodiesel is used for a long period of time. In Fig. 8, it is possible to see the average values and their percentage change of the individual samples of newly developed biofuels and their comparison with the reference sample during the discrete measurement of CO_2.

Slight decreases were found in individual measurements in terms of average values and percentage decreases compared to the reference fuel. For the biofuel B1 sample, there was a decrease of 7.9% during the individual discrete measurements and 5.1% during the continuous method. For sample B2, there was a decrease of 4.6% for the discrete measurement and 2.1% for the continuous measurement. In terms of CO_2 as a greenhouse gas, attention is paid to its production during the operation of a diesel internal combustion engine. When biofuel is used in a diesel internal combustion engine, it is assumed that CO_2 emissions are lower compared to diesel during combustion due to the lower carbon to hydrogen ratio. Biodiesel is generally a low carbon fuel and has a lower elemental carbon to hydrogen ratio. From the obtained results of the technical parameters, it was shown that the investigated newly developed biofuels that were published showed a loss of power and torque when compared to conventionally produced diesel. Xue et al. (2011) and Damanik et al. (2018) state that the main reason for the loss of power and torque is the lower calorific value of biofuels. Kaplan et al. (2006) tested a diesel internal combustion engine at full and part load using sunflower oil methyl ester and mineral diesel and their results showed that power loss was between 5% and 10%. In terms of consumption when using newly developed biofuels, consumption in biodiesel is higher compared to conventionally produced fuel. Experiments with the investigated biofuels revealed an increase during the discrete measurements of consumption ranging from 5.67% to 10.95%. Similar conclusions were presented by Armas et al. (2010) where experiments with biofuels found that the fuel consumption of a diesel internal combustion engine fuelled with biodiesel is higher because compensation for the loss of biodiesel heating value is required. Aydin and Bayindir (2010) presented a higher increase in fuel consumption (by 12.9–16%) compared to diesel. Research by Ghadikolaei et al. (2018) reported biodiesel results with less CO_2 emissions than diesel during complete combustion due to lower carbon to hydrogen ratio. The biodiesel types studied had lower CO_2 emission indices than diesel, which is just attributed to the fact that biodiesel is a low carbon fuel and has a lower elemental carbon to hydrogen ratio than diesel.

Conclusion

The present work deals with the evaluation of three types of newly developed biofuels. Their technical, emission, and economic indicators were compared with conventionally produced diesel. The biofuels are evaluated in terms of their impact on the different emission components of a EURO 5 emission class diesel internal combustion engine in a Peugeot 208 vehicle, which is used only for laboratory experiments with low mileage and in good technical condition. The set of experiments was carried out on the vehicle with the selected biofuels, consisting of discrete measurements, during which the values necessary to construct the speed characteristic of the diesel internal combustion engine and to determine the level of selected exhaust gas components were measured. Among the technical parameters, power and torque drop were monitored for each biofuel. Decrease is attributed to lower values of the calorific value of biofuels and higher values of viscosity and density. For consumption, an increase in average vehicle consumption was found for all the types of newly developed biofuels, which was due to necessary compensation for the low calorific value of the biofuels. For CO_2 emission parameters and absorption coefficient, a positive effect was observed, with a decrease for each of newly developed biofuels compared to conventionally produced fuel.

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