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Influence of Feeding Temperature of Biofuels on Agricultural Engine Performance

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Abstract

The search for alternative energy sources to reduce the use of diesel in the national energy matrix has been studied in a gradual way, with partial insertions of biodiesel to diesel. Parameters such as viscosity change when biodiesel is added to diesel, as this factor directly influences the atomization of the fuel. This paper aimed to evaluate the behavior of renewable biofuels in a 61 hp agricultural engine, by means of dynamometric tests, operating with mixtures of type A diesel S500 and biodiesel, including an analysis of pure diesel (0% biodiesel) and diesel blend with 20% biodiesel, heated with a system before the injection pump, at temperatures of 45 °C, 65 °C, and 85 °C. The highest values were maximum torque of 208.7 N m, maximum power of 55.3 KW, and specific consumption of 236.9 g KW h^{-1} at 45 °C. The viscosities of the mixtures were also determined using the 40 °C test temperature, as suggested by ASTM D 445, followed by the ANP, as well as temperatures studied, and the cSt values of the blends at 65 °C and 85 °C were below the minimum limit established by ANP.

Keywords: biofuel blends, dynamometric test, performance indices, feeding temperature

1. Introduction

Global warming is considered a climatic phenomenon of great extension, in which the increase in global mean surface temperature is associated with factors that are independent of man, such as inconstancy in solar activity, atmospheric physicochemical composition, tectonism, and volcanism. One should also consider anthropogenic actions such as greenhouse gas emissions from burning fossil fuels, in particular coal, petroleum byproducts, industries, refineries, engines, and fires, among others, in which CO_2 is considered the main culprit (Silva & Paula, 2009). Special attention should be given to the energy sector, as it represents two-thirds of global emissions. In this context, the electricity sector accounts for 42%; transportation, 23%; industry, 19%; residential areas, 3%; and others, 7% (IEA, 2015). According to Peterson (2009), in the agricultural sector, the factors that contribute to greenhouse gas emissions comprise mechanized activities, alongside deforestation for agricultural purposes.

Considering that the global population already exceeds 7.4 billion, it is clear that energy demand requires sustainable alternatives. That is, there is a need to replace fossil fuels with sources that emit less CO_2 (Hodgson, 2008). The European Union has sought to implement a mitigation plan that includes the use of 27% renewable energy by 2030 (European Union, 2017).

With increasing industrialization, there is also a growing demand for fossil fuels, causing reserves of these fuels to be running at an alarming rate worldwide. Even with the development of new technologies for fossil fuel extraction, such as the pre-salt in Brazil, these fuels will not be enough to meet this growing demand (Shahir et al., 2015).

As the global transportation sector is among the major contributors to emissions (Doman & Chase, 2015), biofuels have been used as one of the most viable alternatives to fossil fuel substitution to reduce greenhouse gas emissions.

Aiming to be less dependent on non-renewable energy sources, the Brazilian energy matrix is becoming more adequate, providing alternative sources of renewable energy sources (Bezerra, 2016). As a mandatory practice, established by Act 13,263/2016, the addition of biodiesel to diesel in gas stations this addition will reach 10% by 2019.

Parameters such as viscosity and specific mass of the fuel are important factors for atomization, influencing combustion efficiency (Carvalho et al., 2014). According to Carvalho et al. (2014), the use of pure biodiesel can alter the quality in the atomization.

Considering that biodiesel properties are different from diesel and aiming to contribute with technical information to collaborate with energy policy advancement, this study aims to evaluate the performance of an agricultural engine operated with 20% biodiesel in a blend with diesel in (without mixing), subjected to feed temperatures of 45 °C, 65 °C, and 85 °C.

2. Material and Methods

The performance tests of the agricultural engine were carried out in the Agricultural Machinery, Tractor and Engine Laboratory (LAMA). To determine the viscosity, the Biofuels Laboratory was used. Both are located at the State University of Western Paraná (UNIOESTE), Cascavel Campus, Paraná, Brazil, with latitude 24°59′21.3″ S, longitude of 53°26′58.3″ W and an altitude 755 m.

The experimental design was subdivided plots, stopping that the difference between the tanks was applied to the test of Tukey to 5% of significance after the acceptance of the premises ANOVA.

To evaluate the performance of the agricultural engine, a Massey Ferguson tractor, MF 265, model, with a 4 × 2 transmission, presenting 1,076 hours of use in its hour meter, was used. The technical data of the agricultural tractor, according to the manufacturer, are described in Table 1.

Table 1. Technical data of the tested agricultural tractor

Manufacturer	**Massey Ferguson**
Model	MF 265
Power	61 hp at 2,000 rpm
Maximum Torque	23. mkgf at 1,300 rpm
Brand	Perkins
Model	AD4.203
Number of Cylinders	4
Injection	Direct
Angular speed in PTO	540 rpm

The tractor tested had a power takeoff (PTO) a single speed of 540 rpm, including a splined shaft with 6 grooves and 35 mm in diameter, which was used to connect the tractor with the dynamometer via its own drive shaft for dynamometric tests.

The tractor's original fuel tank was disconnected from the fuel feed system and replaced by a separate tank where biofuel the blends were placed. From the tank, the fuel passes through the flowmeter to the heating system, reaching the injection pump. The original tractor filter before the injection pump was ignored, as the flowmeter includes an internal filter. In each test in the different blends, the hoses were drained and the remaining fuel in the tank was withdrawn.

Figure 1 shows a schematic representation of how the test for collection of the research data was set up, in which the flowmeter was connected via cable to the dynamometer to send fuel consumption information. The dynamometer sends performance information via Bluetooth to the EGGERS PowerControl® v2.1 data acquisition software.

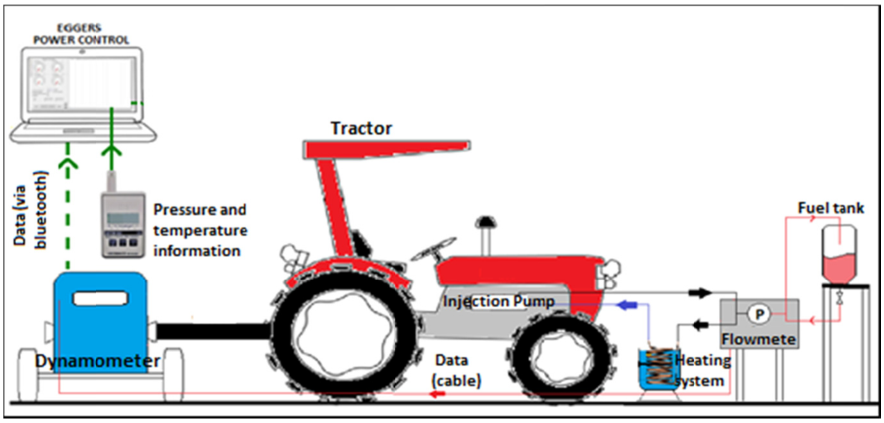

Figure 1. Schematic demonstration of the experiment

Each day, before starting the performance tests, a procedure was carried out to reach working conditions, in which the tractor was accelerated to a rotation near 2000 rpm and a load was manually applied to the dynamometer for a period of approximately 20 minutes. This procedure measured the coolant and engine oil coolant temperatures.

For the torque and power measurements, an Eggers mobile dynamometer, PT170 model, was coupled to the PTO of the tractor with the principle of operation of the magnetic brake by eddy currents (Foucault currents).

The dynamometer was connected to the tractor mechanically by means of special drive shaft for dynamometric test, of the angular speed 540 rpm, which features fast coupling at its ends. The tests were performed with operations as recommended by the manufacturer of the Eggers dynamometer.

The control and configuration of the dynamometer was done with the Eggers PowerControl® v2.1 software programs, being supplied with temperature and atmospheric pressure data for correction of the presented values. For this procedure, the Greisinger thermo-hygrometer, GFTB-100 model, was used.

In conjunction with the dynamometric tests, measurements of the specific consumption (g kW^{-1} h^{-1}) and hourly fuel consumption (l h^{-1}) were carried out using an Eggers flowmeter, FM3-100 model, connected to the fuel injection system tractor. The manufacturer recommends that air be purged from the system and prior to starting the measurement.

For fuel heating in this work, a device was used after the flowmeter and before the fuel injection system of the agricultural tractor. The device was manufactured with a spiral coil with approximately 15 centimeters in diameter and with 10 coils, with a copper tube with approximately 6 mm in internal diameter, being later inserted in a metal container in the form of a cylinder with approximately 25 centimeters in diameter and 20 centimeters in height.

In the metal cylinder, an electric resistor with 1,500 watts in power and voltage of 127 volts was attached. The metal vessel was filled with water, which was heated by the electric resistor. The thermal exchange was performed by the coil, which was responsible for heating the fuel. To conduct the fuel from the coil to the injection pump, a PU polyurethane pipe, coated with a thermal blanket, was used.

The temperature measurement was performed with two temperature sensors, comprising a Type J thermocouple, which was placed in the water to carry out the control, and a rod-type PT 100 sensor, introduced at the injection pump inlet, for temperature monitoring of biofuels feed.

Temperature control was performed using a Novus data logger, FieldLogger 512k model. An on-off control based on the water temperature, monitoring the temperature values before the injection pump, was implemented. To activate the resistor, the data logger triggered a relay output, in which a counter was connected to drive the resistor. The data logger was also programmed to record the temperature values every second.

The fuels used in the agricultural engine performance tests were type A S500 pure diesel, donated by a distributor of petroleum materials in the region of Cascavel, Paraná, Brazil. The biodiesel from the blends was donated by a company from the biodiesel manufacturing branch located in the region of Marialva, Paraná, and has a composition of 68% the soybean oil, 25% beef fat, 5% pig fat, 2% and poultry oil.

The mixtures applied in the tests were prepared at the LAMA, the proportions of the mixtures being measured through a measuring cylinder graduated in milliliters (ml). The sequence of the blends was filled into the diesel fraction. being stirred after preparation and before use, for about 5 minutes.

A Cannon-Fenske capillary viscometer was used, which was dipped in a water bath at a set temperature of 40 °C, which is used by ASTM D 445 and followed by ANP for the determination of viscosity. Tests were also applied at 45 °C, 65 °C and 85 °C—the temperatures studied in this study.

For the performance indices, the following were calculated: elasticity index (Equation 1), torque reserve (equation 2) and rotation reserve (Equation 3). The equations are presented by Mialhe (1996), with values obtained from those measured in the tests. These combined parameters are important in the decision-making process of the field works, so that a greater performance can be obtained with the machine (Iacono, 2017).

Elasticity index (IE):

$$\mathrm{IE} = \left(\frac{\mathrm{Tmax}}{\mathrm{Tpmax}}\right) - \left(\frac{\mathrm{RPMpmax}}{\mathrm{RPMtmax}}\right) \tag{1}$$

Where,

Tmax: Maximum torque observed (N m); Tpmax: Maximum power torque observed (N m); RPMpmax: Maximum power rotation (RPM—revolutions per minute); RPMtmax: Rotation at maximum torque (RPM—Rotations per minute).

Torque reserve [%]:

$$\mathrm{RT} = \left(\frac{\mathrm{Tmax}}{\mathrm{Tpmax}} - 1\right) \times 100 \tag{2}$$

Where,

Tmax: Maximum torque observed (N m); Tpmax: Maxim power torque observed (N m).

Rotation reserve [%]:

$$\mathrm{RR} = \left(\frac{\mathrm{RPMpmax}}{\mathrm{RPMtmax}} - 1\right) \times 100 \tag{3}$$

3. Results and Discussion

The data resulting from the viscosity test were subjected to analysis of variance at a 5%significance level. The mean viscosity values of the tested fuels are presented in Table 2.

Table 2. Mean viscosity values of the fuels tested (cSt)

Biodiesel Percentage	Temperature (°C)			
	*40	45	65	85
0	2.39Aa	2.02 Ab	1.47 Ac	1.08 Ad
20	2.53 Ba	2.20 Bb	1.63 Bc	1.22 Bb

Note. Mean values followed by upper case letters on the column and mean values followed by the same lowercase letters on the row indicate that there was no significant difference by the Tukey test at 5% error probability.

*Temperature used by ASTM D 445 followed by ANP.

The variation of the viscosity in B0 at 40 °C to 85 °C decreased by 54.8%. For B20, this decrease was 51.7% (Table 2). This decrease in viscosity with increasing temperature was also observed by Gabriel (2014), which worked with diesel and coconut biodiesel blends. For the B0 mixture, the difference in viscosity between 40 °C and 80 °C was 45.5%, while for the B20 blend with coconut biodiesel, the viscosity difference between 40 °C and 80 °C was 43.6%. It can be seen that the addition of biodiesel in the diesel influences the viscosity parameter, and that for all temperatures, the B20 mixture was statistically higher than fuel without biodiesel (B0).

According to Shahir et al. (2014) and Barabás et al. (2010), the viscosity has an influence inversely proportional to temperature and has a direct relation to density, and viscosity can affect the atomization quality, fuel drop size, and ignition quality.

For the temperature values of 65 °C and 85 °C, the mixtures were below the viscosity value established by ANP Resolution 50/2013 for Type A diesel, which is 2.0-5.0 cSt, as shown in Figure 2. According to Shahir et al.

(2014), in the case of very low viscosities, leaks in the fuel system and formation of very small droplets in the atomization can directly influence the performance of the engine. The viscosity is also part of the internal seal of the injection pump. With the decrease in viscosity, there may be loss of pressure.

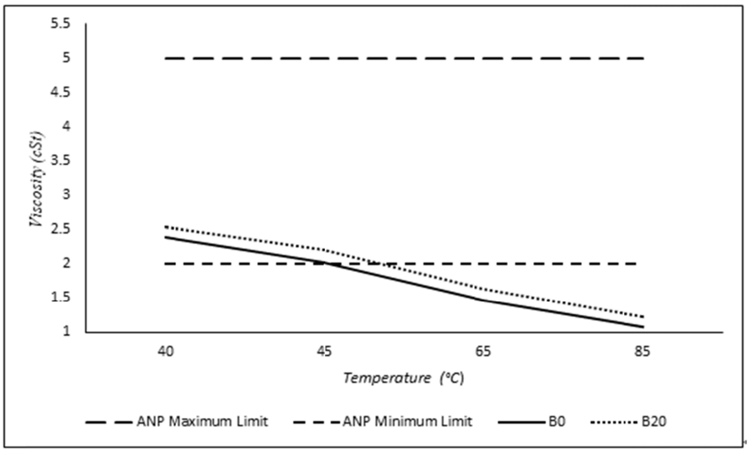

Figure 2. Viscosities of the tested mixtures

The data resulting from the dynamometric performance test were submitted to analysis of variance at 5% level of significance. The mean values of the parameters are presented in Table 3.

According to Mialhe (1996), the specific consumption point shows the highest mechanical efficiency of the engine, in which the highest amount of energy generated by combustion is transformed into mechanical work, with lower energy consumption. In Table 3, the values of specific consumption of fuel had a decrease with the increase in temperature, a fact also observed by Machado (2008), who verified that with the increase of the temperature of the biofuels, there is a decrease in the viscosity and density, as well as a decrease in specific consumption. The author reports that with the decrease of fuel viscosity, internal losses occurred in the injection pump, causing less fuel to reach the combustion chamber. Statistically, the highest value was 236.9 g KW h^{-1} at 45 °C and the lowest value was 223.5 g KW h^{-1} at 85 °C (Table 3). For hourly consumption values, there was no difference. The mixing factor was also not influential significant for the values of specific consumption and hourly consumption.

Table 3. Difference between means for farm engine performance variables

Parameter	Temperature			Mixture	
	45	65	85	0	20
Maximum power [KW]	55.3a	54.2 b	53.8 b	54.4 a	54.4 a
Maximum power torque [N m]	164.8 a	159.7 b	160.3 b	161.0 a	162.2 a
Maximum power rotation [RPM]	2205 a	2189 a	2162 a	2197 a	2174 a
Maximum torque [N m]	208.7 a	203.8 b	202.8 b	205.4 a	204.8 a
Maximum torque rotation [RPM]	1228 a	1203 a	1087 b	1168 a	1178 a
Specific consumption [g KW^{-1} h^{-1}]	236.9 a	232.9 ab	223.5 b	230.3 a	232.0 a
Hourly consumption [l h^{-1}]	12.7 a	12.1 a	10.6 a	11.3 a	12.3 a
IE	2.3 b	2.3 b	2.5 a	2.4 a	2.3 a
CSC [%]	26.6 a	27.7 a	26.6 a	27.6 a	26.2 a
RR [%]	79.7 b	81.9 b	100.2 a	89.0 a	85.5 a

Note. Mean values followed by the same lowercase letters indicate that there was no significant difference by the Tukey test at 5% of error probability.

For the maximum torque values (Table 3), there was a decrease as a function of the increase in temperature. The highest value was 208.7 N m for the temperature of 45 °C, statistically differing from the other temperatures, the value of 202.8 N at 85 °C being 2.8% less than the maximum torque at 45 °C. Machado (2008) obtained results that showed a decrease in the torque value, which is related to specific consumption, as the less the amount of energy available through the fuel mixture, the lower the developed torque.

Table 3 also shows the maximum power values, which had a reduction in the values with the increase in temperature. The highest value being 55.3 KW at 45 °C, differing if statistically from the other temperatures, and the lowest value was 53.8 KW at 85 °C. One should consider the reduction in torque and specific fuel consumption, which also showed a decrease as a function of the temperature increase. The blend factor did not present a statistical difference. The values of maximum power rotation were not influenced by temperature and mixing, and were statistically identical.

The elasticity index (IE) value increased as a function of temperature increase, with a statistically higher value of 2.5 to 85 °C, being 8.7% higher than the elasticity index at 45 °C. This increase in the elasticity index occurs because the maximum torque rotation decreased as a function of the temperature increase, the lowest value being 1,087 rpm at 85 °C, demonstrating statistical difference. The blend factor had no influence on the elasticity index parameters and maximum torque rotation. When observing the maximum power torque parameter, the highest value was 164.8 N at 45 °C, which was statistically different from the other temperatures, and the blend factor had no influence, even with the parameter of the bearing capacity of the conjugate (BCC), which was not influenced by temperatures and blends.

For the rotation reserve (RR) values, the temperature was influential, the highest value being RR 100.2% at 85 °C and the lowest value being 79.7% at 45 °C, with a difference of 20.5% between the temperatures of 85 °C and 65 °C. The blend factor was not influential for this parameter. The rotation reserve is calculated as a function of the maximum power rotation and maximum torque rotation. The maximum power rotation values were not influenced by the temperature, but the maximum torque rotation values decreased with increasing temperature, reaching the smallest value at 85 °C, which explains why the rotation reserve parameter has the highest value at 85 °C.

4. Conclusion

The fuel supply temperature influenced the performance of the agricultural engine. With the increase in temperature, specific consumption, maximum torque and maximum power showed a reduction, the lowest values being 85 °C, although the elasticity index and rotation reserve values had an increase, according to the increase in the temperature of the fuel, which shows that the use of heated biofuels can be useful depending on the agricultural operation.

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