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CONSUMPTION STUDY OF DIESEL ENGINE SYSTEM USING BIODIESEL

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Abstract. *This paper presents an experimental analysis of the variation in fuel consumption of a single-cylinder mechanical injection diesel engine system, coupled with a centrifugal pump in a closed system. The engine tests with pure diesel (B0) are presented; the results for this fuel formulation are used as reference in comparison to fuels containing only biodiesel and mixtures of diesel and biodiesel in different proportions. The mixtures used, described by biodiesel content, are: 8% (B8); 10% (B10); 20% biodiesel (B20) and pure biodiesel (B100). The biodiesels are manufactured using the methyl and ethyl processes of soybean oil. Two different tests are carried out: in the first the accelerator position is kept constant; in the second the engine's rotation is kept constant. In the test where the accelerator position is kept constant, exit pressures are recorded for each regulation of the accelerator and fuel mixture.*

Keywords: *biodiesel, soybean, engine, consumption, diesel.*

1. INTRODUCTION

In Brazil, road transportation is one of the main ways to transport goods through the national territory; besides road transportation rail transport and ship transport are also used. This sector has as its predominant use of petroleum-derived fuels (E. V. Barros), the main energetic sources consumed by this Market is the diesel (D.H. Qi, 2010).

Taking into account environmental issues, presented by various research entities, such as the IPCC, and international agreements, Brazil has increased investment in alternative fuel sources to those petroleum derivatives, one of these is biodiesel, that appears as an alternative to diesel. In 2004 was started the National Program for Production and Use of Biodiesel (PNPB) made by National Agency of Petroleum, Natural Gas and Biofuels (ANP) with the objective of defining norms of regulation, in 2005 the addition of 2% of biodiesel in diesel became mandatory with the law 11.097/2005, ever since this value has been increasing, today its current value is 8%, with the goal of reaching 10% in 2019, as stipulated by the law 13.263/2016.

Due to the regulation and mainly because of the national goals defined by the government, national production of biodiesel has increased. This increases the need to advance the development of the production methods and the research for new oilseeds that might serve as feedstock. As a consequence to these advances in the use of biodiesel in diesel engines, increases the necessity of researches of behavior of compression-ignition engines and the effects that this change might cause, since biodiesel is a fuel similar to diesel, but not the same.

The study analyses the consumption of a single-cylinder diesel engine when subjected to different loads, distinct regulations of the acceleration, and different fuels. The study is comparative, the reference is the behavior presented by the engine when tested with pure diesel S10 (B0). The reference data is confronted with data of the system when soybean biodiesel (B100) and mixtures of soybean biodiesel and diesel, in proportions of 8% (B8), 10% (B10) and 20% biodiesel (B20).

The choice of soybean biodiesel was made due to his importance and predominance in national scenery of biodiesel industries, as can be verified in Table 1, where the production of biodiesel, separated by oilseeds, is presented. Soybean is responsible for 77,7% of all of Brazil's production.

Table 1: Feedstock used in the production of biodiesel in Brazil

Feedstock	Used in the production off Biodiesel (B100) (M ³)										15/14
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	%
Total	69.012	408.005	1.177.638	1.614.834	2.387.639	2.672.771	2.719.897	2.719.897	2.921.006	3.938.873	15,32
Soy Oil	65.764	353.233	967.326	1.250.590	1.980.346	2.171.113	2.105.334	2.231.464	2.625.558	3.061.027	16,59
Cotton Oil	-	1.904	24.109	70.616	57.054	98.230	116.736	64.359	76.792	78.840	2,67
Animal Fat	816	34.445	154.548	255.766	302.459	358.686	458.022	578.427	675.861	738.920	9,33
Other fatty											
Materials	2.431	18.423	31.655	37.863	47.781	44.781	39.805	46.756	37.255	60.086	61,28

Source: Statistical Yearbook ANP 2016

2. EXPERIMENTAL PROCEDURE

The soybean biodiesel was provided by IVIG’s biodiesel laboratory and it was produced using ethanol. The diesel was donated by “Distribuidora de Petróleo Ipiranga”. The biodiesel produced with methanol was provided by Laboratory of Thermosciences – Latermo/UFF.

The biodiesel/diesel mixtures were produced according to the following proportions: 0% biodiesel and 100% diesel; 8% biodiesel and 92% diesel; 10% biodiesel and 90% diesel;

20% biodiesel and 80% diesel; 100% biodiesel and 0% diesel. Such mixtures are referred by B0, B8, B10, B20 and B100, respectively. These proportions were chosen by several reasons: 8% biodiesel in regular fuel is the current portion of biodiesel mixed with diesel in Brazil, 10% is the goal for 2019, and 20% is a proportion used in other countries. The pure biodiesel and its mixtures were characterized according to ANP’s resolution number 45 of 8/25/2014.

The experiment was done using a diesel engine, Lintec D50, powered pump assembly linked to a water tank. At the exit of the pump there is a globe valve to vary the load in the system by restricting the flow, after the valve there is a flowmeter and at the exit of the centrifugal pump the system also has a manometer. The tests were performed using two different principles; the first consists in operating the system limiting the fuel injection by marks in the acceleration system, for each mark made, the behavior results are obtained for different flow restrictions determined by the valve, measuring consumption is obtained in order to compare performance of different fuels, with the acceleration fixed. In the second principle the consumption was measured regulating the accelerator so that the rotation was the same, i.e., rotation was the fixed variable. The Figure 1 shows the steps of the experiment.

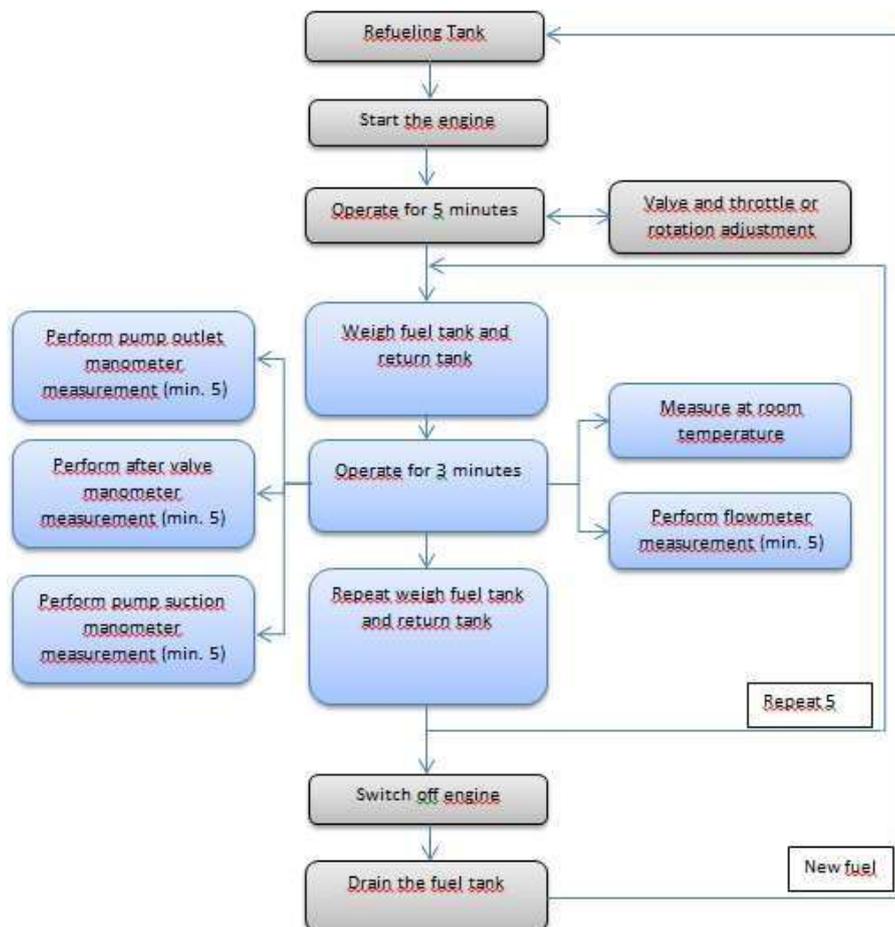


Figure 1. Steps of the experiment.

The study was started by the determination of the specific mass, which was done through the use of a pycnometer being based norm (*Norma no NIE-DIMEL-039*) and was made at a temperature of 20 ° C, using a balance of 0.0001g, where 7 measurements of density were taken for each biodiesel. In the viscosity study a Haake RS50 rheometer was used to find the dynamic viscosity, from this and the specific mass the kinematic viscosity was calculated. This study was done at 40 ° C controlled by a bath connected to the rheometer and with an acceptable variation of 0.1 ° C.

In addition to the fuel varieties and their mixtures, the experiment on the engine has the following variations: two valve opening positions that will be combined with two throttle positions and will be regulated by rotation in rpm. The positions of the valve Figure 3, being two, will be divided into Max and Min, where Max is the maximum valve aperture and Min is the minimum aperture, while the accelerator positions, Figure 2, will be divided into 3100 and 2200, where 3100 is the maximum acceleration and 2200 is the minimum acceleration (Da Silva, 2014).



Figure 2: Accelerator



Figure 3: Valve

3. RESULTS AND DISCUSSION

Viscosity analysis was done, as previously mentioned, using a Haake RS50 rheometer. With the rheometer we obtained the dynamic viscosity for the two pure biodiesels at a temperature controlled by a 40 ° C bath. The behavior of the two fluids was the same, as we can see in Figure 4 and 5, this behavior was expected since it corresponds to a Newtonian fluid where the viscosity is constant independent of the shear rate. The dynamic viscosities of the two biodiesels gave different results, these results were reflected in a bigger difference in kinematic viscosity, which was calculated from the dynamics and the specific mass.

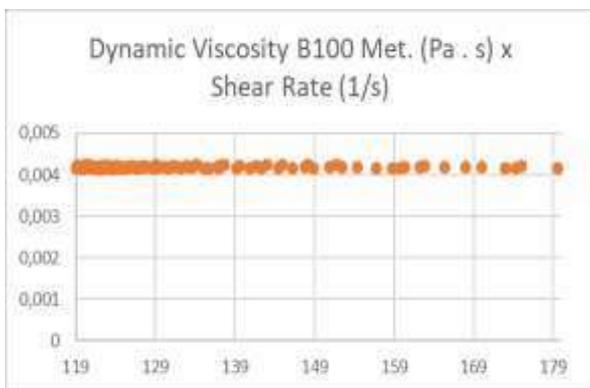


Figure 4: Dynamic Viscosity B100 Met.

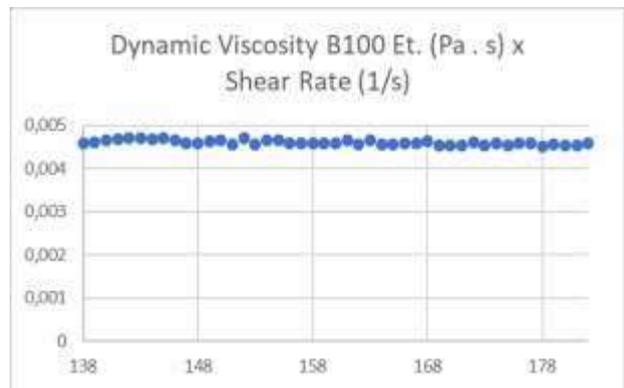


Figure 5: Dynamic Viscosity B100 Et.

In the analysis of specific mass made through the use of pycnometer and bath at 20 ° C, it was noticed that the two B100 biodiesel, soybean biodiesel that used methanol in the manufacture and the one that used ethanol, meet the requirements made by ANP, since ANP regulations require that the specific mass be between 850 kg / m³ and 900 kg / m³. As shown in Table 2, the specific mass of the two fuels fell within this range and also shows that they have close results, similar to those presented in other papers (R. Pereira, 2007; M. Silva, 2017).

Tabela 2: Specific mass and Kinematic Viscosity

Fuel	Specific mass (Kg/m ³)	Kinematic Viscosity (mm ² /s)
B100 Met.	879,74	4,7483
B100 Et.	878,87	5,2663

The values of Table 2, kinematic viscosity, were found from the calculation:

$$v = \frac{\eta}{\rho}$$

where we have the dynamic viscosity divided by the specific mass, resulting in kinematic viscosity.

As shown in Table 2, the two results are within the limits established by the ANP that allows a variation of 3 mm²/s to 6 mm²/s, consistent behavior (O. Valente, 2010). Once these parameters were defined, the motor tests were started.

As shown in the methodology, consumption was calculated for each combination of rotation, valve position and fuel separately. The acronyms Max and Min mean maximum and minimum, respectively, and the numbers accompanying them show the accelerator position in rpm. For fuels, the abbreviation (Met) and (Et) were used to describe the alcohol used in the biodiesel production cycle, with (Met) methyl alcohol and (Et) ethyl alcohol.

With the consumption data the average consumption of each fuel was calculated for all accelerator and valve positions, this way it's easier to see the difference between each fuel, reducing the influence of the characteristics of the engine itself. To compare the behavior of each fuel when confronted with the standard fuel for which the single-cylinder diesel engine of the pump has been designed, a graph was created, with the calculated average, of the difference in percentage of each fuel when compared to pure diesel (B0).

In the graph of fuel consumption B – Met., Figure 6, we see a comparison of methyl biodiesel (B100Met) and its blends with diesel (B0). It shows that the effect, on fuel consumption by time, of the throttle position set by the rpm is much bigger than the effect of valve throttling. This behavior was reflected in all fuels. The behavior of biodiesel blends B8 and B10, produced with metanol, showed an almost null consumption variation, resulting in an increase in consumption of less than 1% in both cases. From the B20 the differences in consumption are beginning to be more significant, is a still discrete variation when we analyze the average consumption graph (med) (O. Ozener, 2009, A. Tsolakis, 2007, Almeida, 2015, M. Canakei), but that is visible in the corresponding line in percentage, where it presents an increase of 3.06% in consumption. As expected, the biggest difference lies with the B100, in it the increase in consumption reached 14%, corresponding in a variation of 4.97 g/min of average consumption in the B0 to 5.67 g/min of average consumption in the B100.

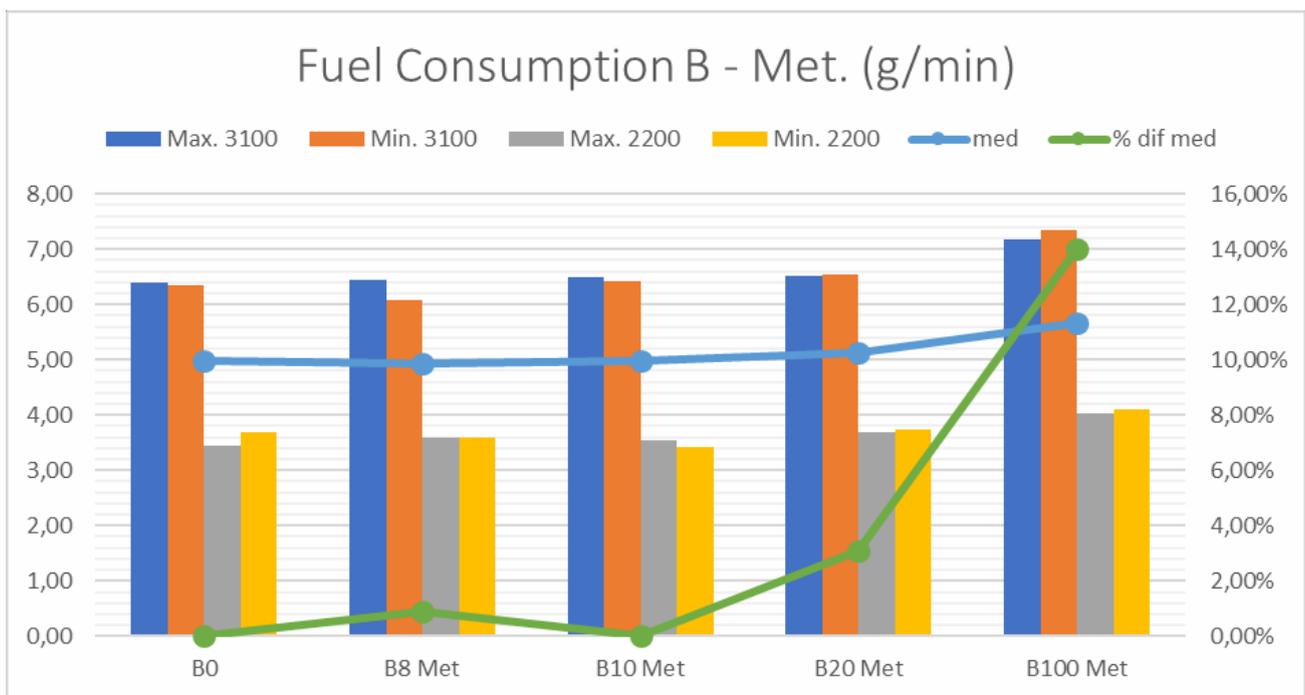


Figure 6: Consumption Graphic B-Met.

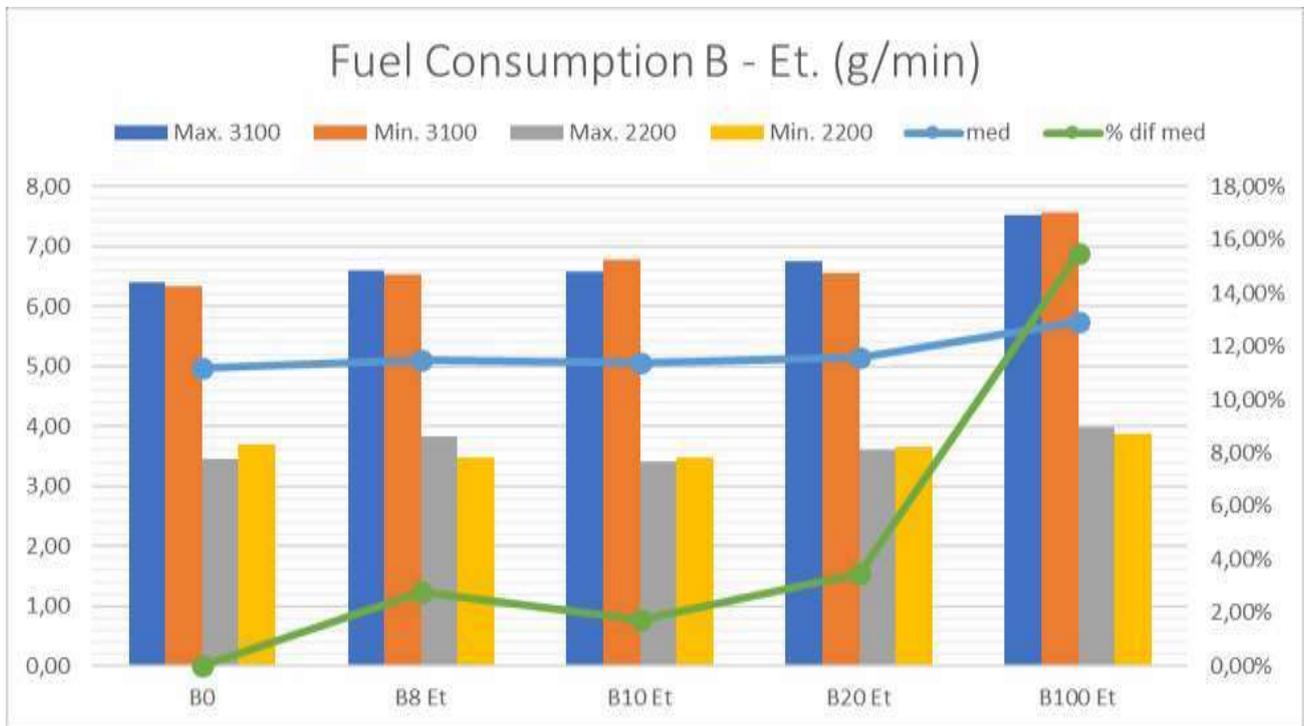


Figure 7: Consumption Graphic B-Et.

In the graph of fuel consumption B – Et., Figure 7, there is the same behavior trend observed in graph 1, but with different magnitudes. Concerning to the variation of rotation and valve opening, the behavior follows the same trend as in graph 1, where the rotation influences more than the throttling of the valve. Unlike biodiesel of methyl process, biodiesel of ethylic process presents a bigger difference in low concentrations, as we can see in B8 and B10. The B20 of the ethyl cycle is close to the order of magnitude of the methyl, with a consumption value of 5.14 g/min, representing an increase of 3.49% for the B0. Again, as expected, the largest increase in consumption occurs in the B100, in which case we have a 15.49% increase in fuel consumption.

Figure 8 shows the experiment as a whole, thus observing the differences between biofuels. In the behavior of the average consumption we can see that even the B20 has a behavior close to the constant of both fuels, with consumption slightly higher than ethylene-cycle biodiesel when compared to the methyl-cycle biodiesel, which is apparent when observed by the percentage increase in consumption compared to diesel, where we have the B8Met and B10Met with increases close to 1% and 0.5% while the B8Et and B10Et are around 2%.

The average consumption of biodiesel that was manufactured with ethyl alcohol is higher than that manufactured by the methyl cycle in all proportions. In B20 the two fuels have their smallest difference, where we have the methyl with 3.06% increase, when compared to diesel, and the ethyl with 3.49%, then again they differ in the B100.

In the consumption vs. valve position and rpm graph, Figure 9, we can observe, separately, the behavior of each fuel and mixture for each combination of valve and rotation. It shows that the highest consumption in all cases is given by the B100, this difference is smaller in low rotation. Comparing the two fuels B100, which used methyl alcohol with ethyl alcohol, we can observe that the ethyl had a noticeably higher consumption at high rotation, but at low rotation this was not repeated, having a consumption similar to methyl.

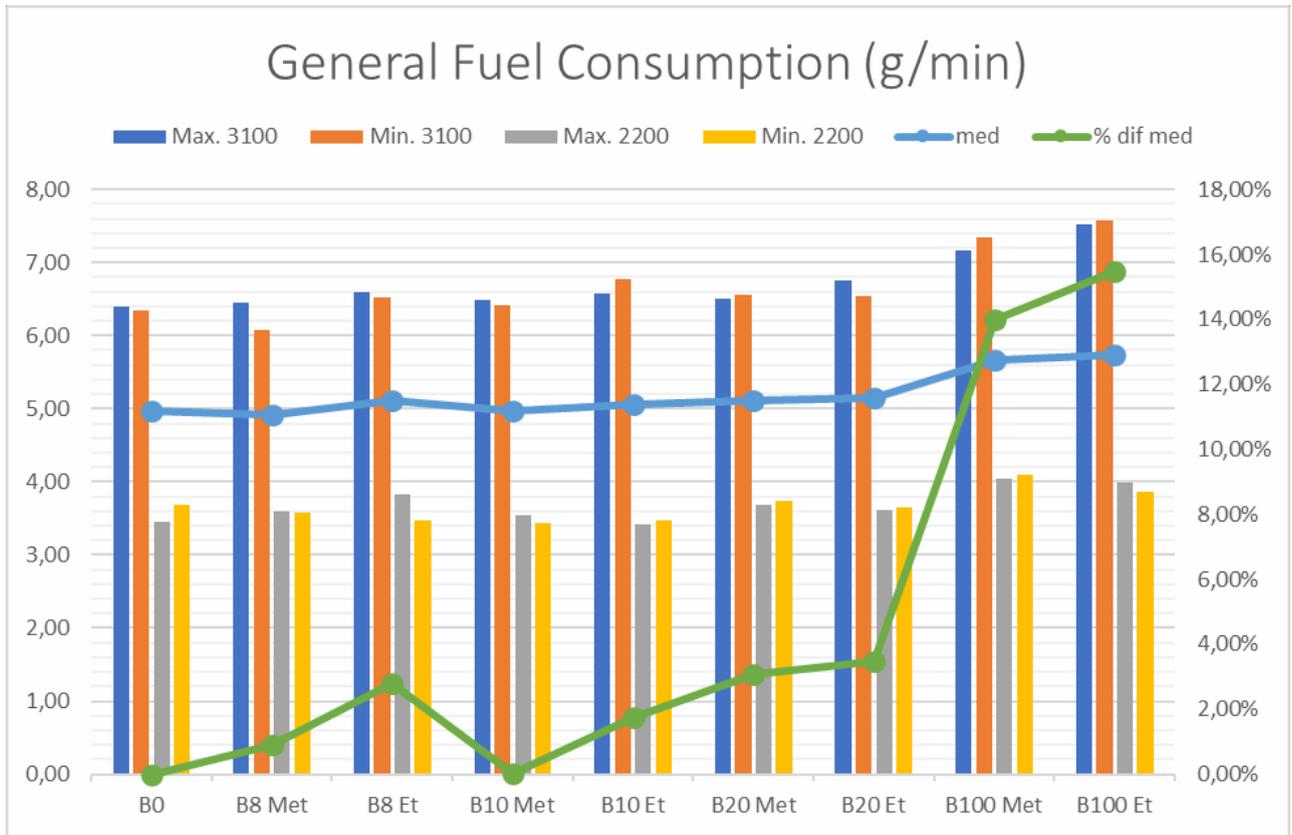


Figure 8: General Fuel Consumption Graphic

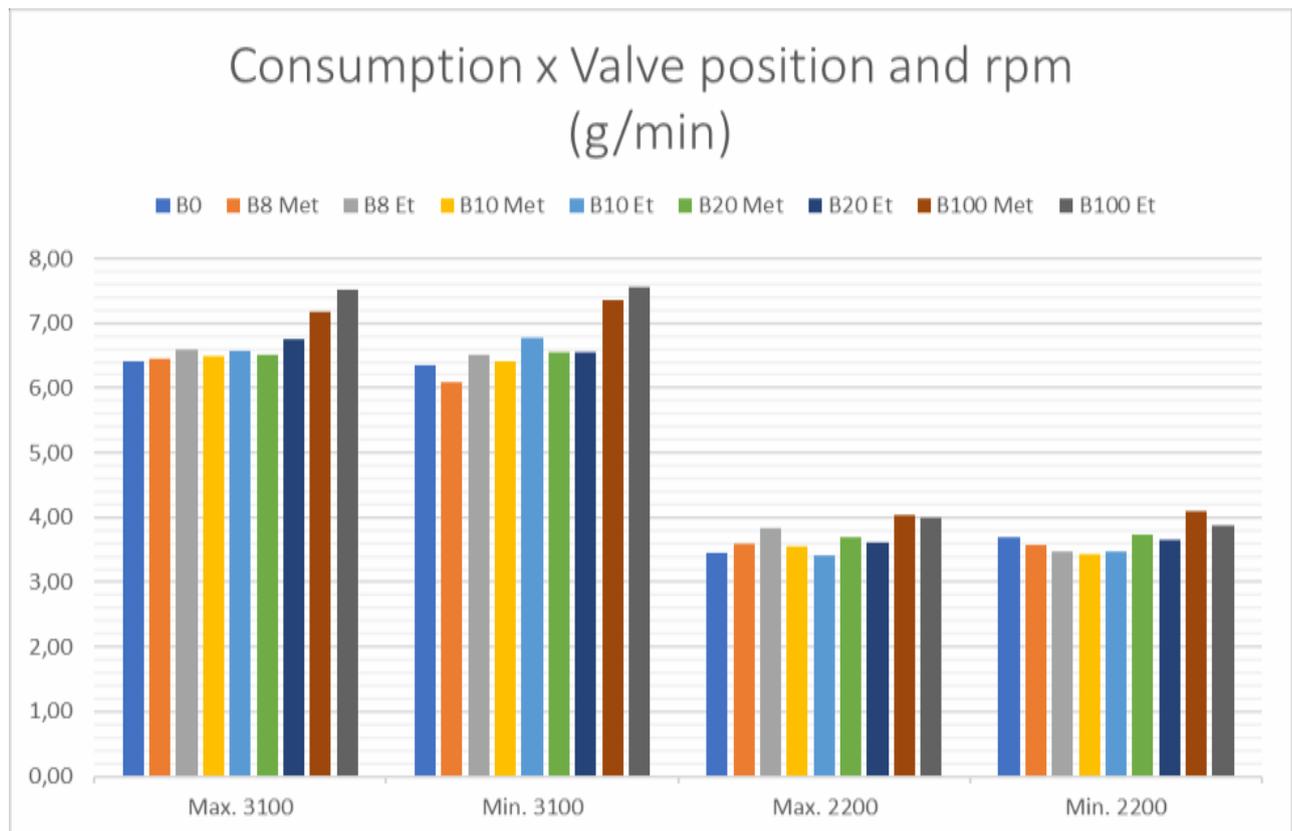


Figure 9: Graphic of Consumption x Valve position and rpm

4. CONCLUSIONS

The motor pump set had no operating problem with all fuels. The biodiesel had their density and viscosity values within the limits of the standard, ANP 45/2014. As expected, their viscosities had behavior of a Newtonian fluid, moreover the viscosity of the biodiesel that used ethanol is higher than the one that used methanol.

The overall behavior of biofuels followed a similar pattern regarding their mixtures and increased consumption when increasing the amount of biodiesel. However, it is clearly noticed that soybean biodiesel that was manufactured with ethyl alcohol had a higher consumption than soybean biodiesel manufactured with methyl alcohol, even with a small difference, its average consumption was always higher when the proportion of biodiesel mixed with diesel was increased and it was maintained when the B100 was used. This difference had the smallest in B20 when it was 0.02g/min or 0.43% higher than ethanol consumption compared to diesel, and the biggest difference occurs with B8 and B10.

It can be observed that the soybean biodiesel manufacturing method can influence fuel consumption. The use of methyl alcohol in manufacturing has a better performance in the engine's consumption, being this alcohol the most used by the industry. Methyl alcohol has a negative side, which is its toxicity and therefore its risk to whoever handles it, which does not happen with ethyl alcohol. From the point of view of sustainability, the use of ethyl alcohol has an advantage over the use of methyl alcohol.

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