EVALUATION OF PERFORMANCE AND EMISSIONS
OF GENSET WITH DIESEL / BIODIESEL

Carlos Henrique Matiolo
Universidade Federal do Paraná, Programa de Pós-Graduação em Engenharia Mecânica, Núcleo de Pesquisa e Desenvolvimento de Energia Autossustentável - NPDEAS
Cx. P. 19011 – 81531-990 – Curitiba, PR, Brazil
carlos.matiolo@gmail.com

João Pedro Woitchy Barbosa
Universidade Federal do Paraná, Programa de Pós-Graduação em Engenharia Mecânica, Núcleo de Pesquisa e Desenvolvimento de Energia Autossustentável - NPDEAS
Cx. P. 19011 – 81531-990 – Curitiba, PR, Brazil
jpwbarbosa@gmail.com

Beatriz Jacob Furlan
Universidade Federal do Paraná, Departamento de Química, Núcleo de Pesquisa e Desenvolvimento de Energia Autossustentável - NPDEAS
Cx. P. 19011 – 81531-990 – Curitiba, PR, Brazil
beatriz.jacob@ufpr.br

Anne Caroline Defranceschi Oliveira
Universidade Federal do Paraná, Programa de Pós-Graduação em Engenharia e Ciência dos Materiais - PIPE
Cx. P. 19011 – 81531-990 – Curitiba, PR, Brazil
annewcaroline@hotmail.com

Erick Cordeiro Kollross
Universidade Federal do Paraná, Departamento de Engenharia Mecânica, Núcleo de Pesquisa e Desenvolvimento de Energia Autossustentável - NPDEAS
Cx. P. 19011 – 81531-990 – Curitiba, PR, Brazil
erickkollross@gmail.com

Lauber de Souza Martins
Universidade Federal do Paraná, Programa de Pós-Graduação em Engenharia e Ciência dos Materiais - PIPE
Cx. P. 19011 – 81531-990 – Curitiba, PR, Brazil
Andrews University, Department of Physics
49104-0380, Berrien Springs, MI, United States
lauber@ufpr.br, lauber@andrews.edu

André Bellin Mariano
Universidade Federal do Paraná, Departamento de Engenharia Elétrica; Núcleo de Pesquisa e Desenvolvimento de Energia Autossustentável - NPDEAS
Cx. P. 19011 – 81531-990 – Curitiba, PR, Brazil
andrebmariano@gmail.com

José Viriato Coelho Vargas
Universidade Federal do Paraná, Departamento de Engenharia Mecânica; Núcleo de Pesquisa e Desenvolvimento de Energia Autossustentável - NPDEAS
Cx. P. 19011 – 81531-990 – Curitiba, PR, Brazil
vargasjvcv@gmail.com

Abstract. *In the past two decades, the Brazilian government has implemented policies that encourage the production and consumption of sustainable fuels, from oilseed vegetables, residual oils or microalgae, at the end of the biodiesel production process. Even when using renewable sources of energy, it is extremely important to identify and minimize the impacts generated on the equipment and the environment. According to the 2019 Statistical Yearbook of the National Agency of Petroleum, Gas and Biofuel (ANP), it is observed that even with a surplus in the international trade of oil and oil products, there is still an external dependence on the by-products obtained in the refining of oil, being the main one diesel. In addition, based on the same report, it can be seen that the production of biodiesel in the last 10 years increased by 337.5%, through RenovaBio, the national biofuel policy, established by Law No. 13,576 / 2017, being its main front the adequacy of biofuels in the national energy matrix. In order to reduce the consumption of oil products, to increase national biofuel technology and to have sustainable energy generation, the Center for Research and Development of Self-Sustainable Energy at the Federal University of Paraná (NPDEAS - UFPR), in partnership with the program of technological research and development Companhia Paranaense de Energia - COPEL, through the project PD 2866-0470 / 2017, regulated by ANEEL, has conducted experiments designed to identify the behavior of mixtures with higher percentages of biodiesel in diesel in genset, such as the addition of microalgae diesel in the diesel / biodiesel mixture, obtaining parameters such as: mechanical and thermal performance, and emissions (O_2, CO, CO_2, NO, NO_2 and NO_2).*

Keywords: *Engine, Genset, Efficiency, Emissions.*

1. INTRODUCTION

Fossil fuels are expected to still exist for some time, but politicians and scientific researchers need to seek alternative sources of energy for environmental preservation (DRESSELHAUS, 2001; BENGTSSON, 2006). The wide discussion of global concerns and their relationship with energy led Smalley (2005) to propose a prioritized list of the ten main problems that humanity must face in the 21st century: 1. Energy; 2. water; 3. food; 4. environment; 5. poverty; 6. Terrorism and war; 7. disease; 8. education; 9. Democracy and 10. Population. Smalley (2005) argued that with energy as a key item at the top of the list, it is possible to solve all other problems, but low-cost energy is the only plausible direction to take. Therefore, energy is the most important factor that affects the prosperity of any society.

Currently, diesel engines play an extremely important role in power generation due to their economy, durability, occupied space, and high knowledge of the equipment. In parallel, ways of replacing conventional diesel oil with alternative fuels is a possible way to reduce environmental problems and be more sustainable. Because it has characteristics such as: renewable and biodegradable, biodiesels are the most plausible alternatives today to replace diesel. Having an improvement in efficiency, and at the same time reducing the pollutants generated, are necessary motivations to study more and more these new biodiesels. Thus, parameters such as combustion, performance and emissions must be studied. (SATSANGI et al, 2018; TAYARI et al 2020; TUCCAR et al 2014)

In what concerns the performance analysis, much is studied about the 1st law of thermodynamics and the thermal efficiency of the 1st law (η_I), combustion efficiency, being commonly applied to evaluate the performance of a diesel engine, however it does not involve fuel sustainability. With this, the thermal efficiency of the 2nd law of thermodynamics, (η_{II}), thermal conversion efficiency, which analyzes the quality of the energy consumed by the diesel engine, must be evaluated, thus having the performance obtained by the machine in comparison to the maximum capacity that engine can perform. (BEJAN, 2016)

Along with this, the large-scale use of diesel engines to produce energy has some type of environmental impact as a side effect. The burning of fuels can pose a threat to the environment as we know it today. Trends in temperature increase combined with the growth of CO_2 emissions have been reported. In addition to CO_2, other gases generated by human activity have a relevant environmental impact, such as methane (CH_4) and nitrogen oxides (NO_x). (Ritchie and Rose, 2014). For internal combustion engines, the term emissions are used to indicate products considered harmful to the humankind and to the environment. The complete combustion reaction, the complete chemical reaction produces CO_2, H_2O as byproducts. However, in not always complete ICE's and the byproducts formed are CO, SO_x, NO_x etc. The proportions of these gases released depend on the fuel, the operating conditions of the engine and the quality of the air-fuel mixture. (BRUNETTI, 2012; FILIPPO FILHO, 2014)

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In order to reduce the consumption of oil products, to increase national biofuel technology and to have sustainable energy generation, the Center for Research and Development of Self-Sustainable Energy at the Federal University of Paraná (NPDEAS - UFPR), in partnership with the program of technological research and development Companhia Paranaense de Energia - COPEL, through the project PD 2866-0470 / 2017, regulated by ANEEL, has conducted experiments designed to identify the behavior of mixtures with higher percentages of biodiesel in diesel in genset, obtaining parameters such as: mechanical and thermal performance, and emissions (CO, CO_2, NO, NO_2; and NO_X).

2. METHODOLOGY

2.1 Equipements and metods

A diesel engine MWM D229 / 4, 4 stroke, and alternator WEG GTA 201 AIHV, with a capacity of 44KW / 55KVA were used to generated experimental data. The generator set is the system used as an electricity generator for NPDEAS. It also produces hot gases used as the energy input for an absorption refrigeration system to produce cold for the NPDEAS building (air conditioning of the building, and cooling for the microalgae culture medium). The absorption refrigeration system also generates heat, producing hot water for industrial consumption.

To characterize the equipment, diesel fuel was first used, adding 11% biodiesel (B11), then 4 more diesel and biodiesel mixtures (B25, B50, B70 and B100) were used. The loads applied on the genset were 12%, 32% and 55% of the total engine load, these percentages being respectively 5kW, 14kW and 24 kW.

The biodiesel used to make the mixtures was produced by Potencial Biodiesel, and the biomass used for its manufacture were. with 67% of soybean oil, 18% of pork grease, and 8% of beef tallow. The diesel is the type S500. Below, in the table 1, is presented the physical characteristics of fuels determined by Laboratório de Análises de Combustíveis Automotivos (LACAUT).

Table 1. Physical characteristics of fuels

Fuel	Density (kg/m3)	LHV* (MJ/kG)
B11	848,900	44,965
B25	853,000	44,210
B50	860,800	42,840
B75	869,900	41,365
B100	879,100	39,942

*LHV: Less heating value

The fuel consumption was measured via mass consumed by a mechanical anthropometric scale. The exhaust manifold temperature was measured with a multimeter Icel Manaus MD-1700. Data of indicated power, brake power, and mechanical efficiency were measured by the equipment energy quality analyzer, Fluke model 434 series I. Gaseous emissions (CO, CO2, SO2, NO and NO2) were measured with the gas analyzer Text 350.

2.2 Mathematical equations

Fuel consumption is given by measuring the fuel consumed, which is done by measuring the variation in the weight of the fuel tank during the experiments. Mass flow is the ratio of the mass of fuel consumed, measured in kg, to the test duration, measured in minutes, as follows:

$$\dot{m} = \frac{m}{\Delta t}\frac{1}{60} \qquad (1)$$

where $\dot{m}$ is the mass flow rate, $\mathrm{kg.s^{-1}}$; m is the mass of fuel consumed, kg; Δt is the test duration, min. Performance characterization is based on engine performance, which is the objective function the performance of the engine. In this study, mechanical, thermal (1st Law of Thermodynamics) and true or rational (2nd Law of Thermodynamics) efficiencies are used.

Mechanical efficiency, η_m, is the ratio of the indicated power, P_i, to the brake power, P_b, done by the shaft.

$$\eta_m = \frac{P_b}{P_i} \tag{2}$$

The first law efficiency, η_I, is the ratio of the indicated power, P_i, to the heat input, generated by the combustion reaction.

$$\eta_I = \frac{P_i}{\dot{Q}} \tag{3}$$

where

$$\dot{Q} = \dot{m}\, PCI_C \tag{4}$$

and $\dot{m}$ is the fuel mass flow rate, kg/s and PCI_C is the fuel lower heat value, kJ/kg.

The second law efficiency, η_{II} is the ratio of first law efficiency to the Carnot efficiency, η_C, as follows

$$\eta_{II} = \frac{\eta_I}{\eta_C} \tag{5}$$

where

$$\eta_C = 1 - \frac{T_L}{T_H} \tag{6}$$

The Carnot efficiency, η_C, is the maximum efficiency that a heat engine can achieve when operating between a heat source the temperature T_H and a heat sink at the temperature T_L. In the present study, T_H is the temperature of the gas at the exhaustion pipes and T_L is the ambient temperature.

Carnot's efficiency, η_C, is the maximum performance that a thermal machine can obtain, between a hot source at temperature T_H and a cold source at temperature T_L. In this work, the temperature T_H is measured at the cylinder head, representing the combustion chamber, where combustion occurs, and T_L is the ambient temperature, i.e., the temperature of the cold tank to which the engine rejects heat.

3. RESULTS

In the Figure 1 is presented the consumption, in L/h, of fuels B11, B25, B50, B75 and B100 for all three loads indicated before. The best result is to the fuel B25, if you compare the average consumption of the three loads, even with this blend having the worst result in the higher load. But if this paraments is analyzed in 55% load, the best blend is the B11. On the other hand, the worst mix is the B100 when is looked consumption average. This was expected because it has the lower less heating value.
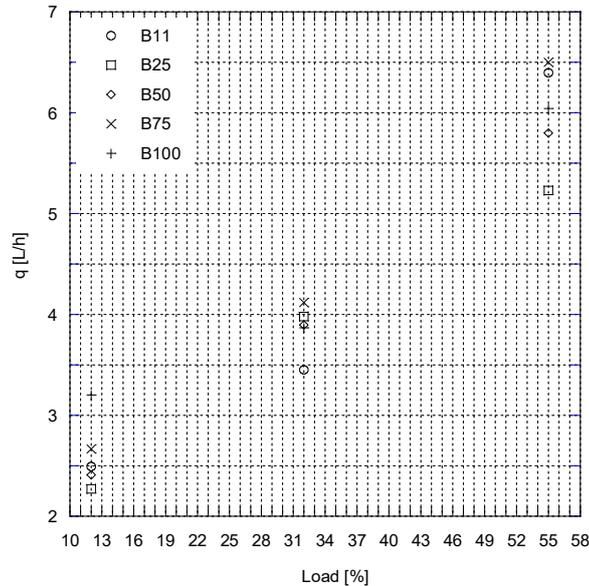
Figure1. Consuption (L/h)

The Figure 2 present: heat generation rate, indicated power and brake power for all the five fuels generated in the three loads. The mixture B11 was the fuels with biggest heat generation average. For the first load did not have any significant variation. For the load of 32%, stands out the blend B100 with lower rate. The higher load, the most expressive value is to B75 that indicated the less value.

For the Indicated and Brake Power was expected the results were near for each other. So did not have a variation that could be represent something of mixtures. Just as featured, the higher power was with the B11 fuel and, the lower was with the B100.
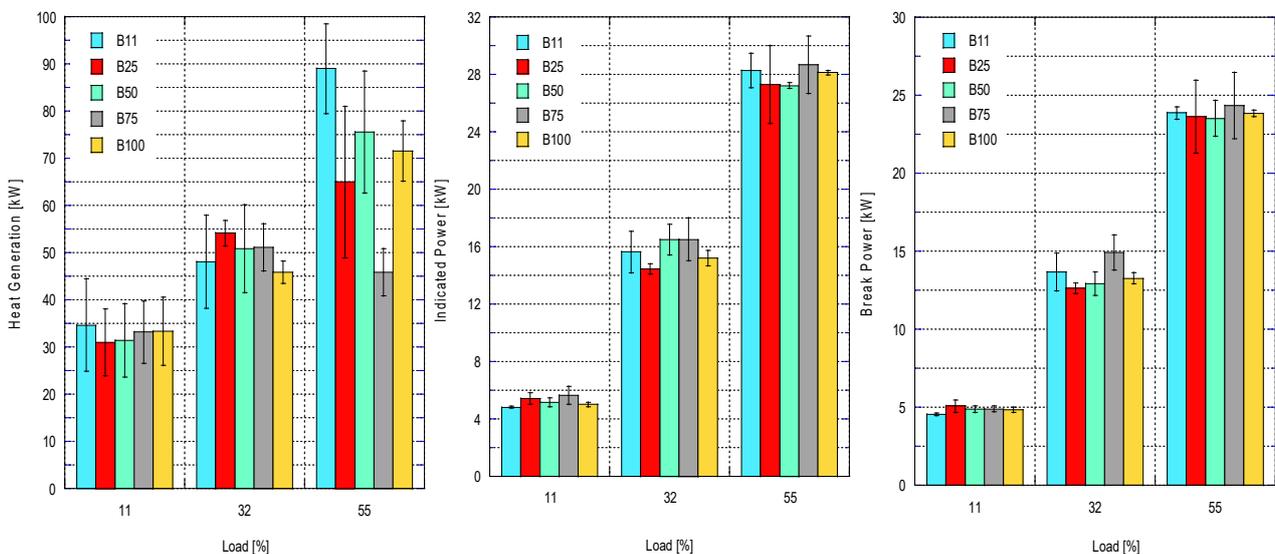

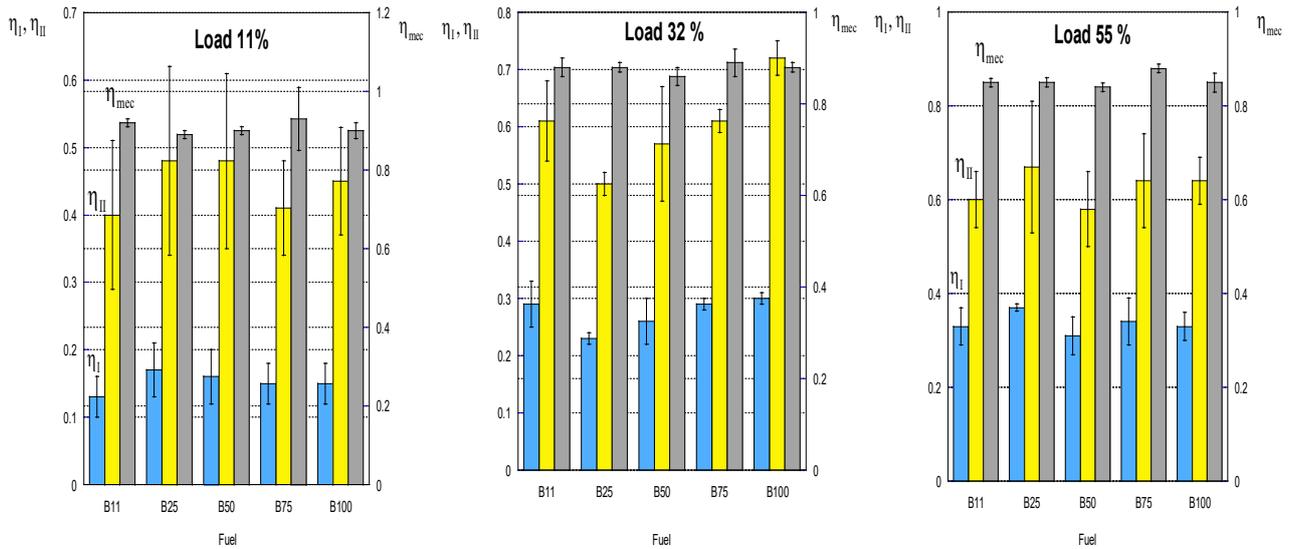Figure 2. Heat generation rate, indicated power and brake power

Carlos Henrique Matiolo, José Viriato Coelho Vargas and Andre Bellin Matiano, João Pedro Woitchy Barbosa, Beatriz Jacob Furlan, Anne Caroline Defranceschi Oliveira, Erick Cordeiro Kollross,
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Figure 3. 1st law efficiency (η_I), 2nd law efficiency (η_{II}) and mechanical efficiency (η_m)

Then engine presented a better result of 1st law efficiency in the load of 55%, and the worst results in the lower load. It shows that what was expected for a thermal machine, having an improvement in efficiency with the growing of the load. With respect to fuels, the B25 was the best in the load of 11% and 55%, but the worst into load 32%. The 2nd law efficiency just has satisfactory results with the lower load, because a diesel engine can get a thermal conversion efficiency around 0,42. And if you look to the others loads, theses results are bigger. It happed in consequence of a low Carnot efficiency got in the end of the tests. For the mechanical efficiency, into the tests the results were the expected, with no great variation.
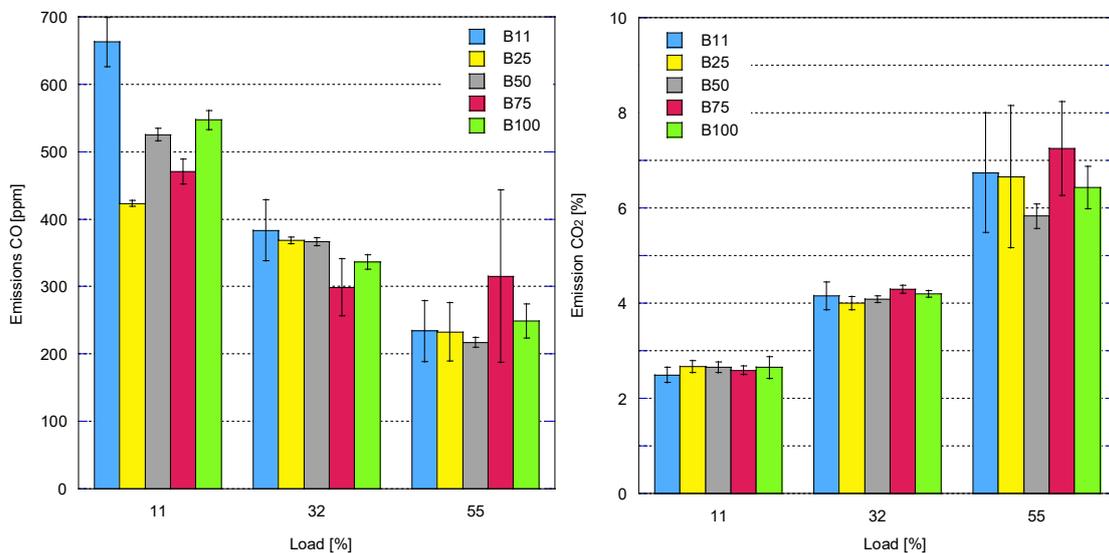
The figure 4. Emissions of CO and CO_2

The emissions of CO, carbon monoxide, is inversely proportional of efficiency the combustion, so this pollutant gas decrease with growth the load. Different of the CO_2, that increase with the efficiency the combustion. The B25 was fuel issued less CO, and the B50 issued less CO_2. The B11 was fuel issued more CO, and the B75 issued more CO_2.
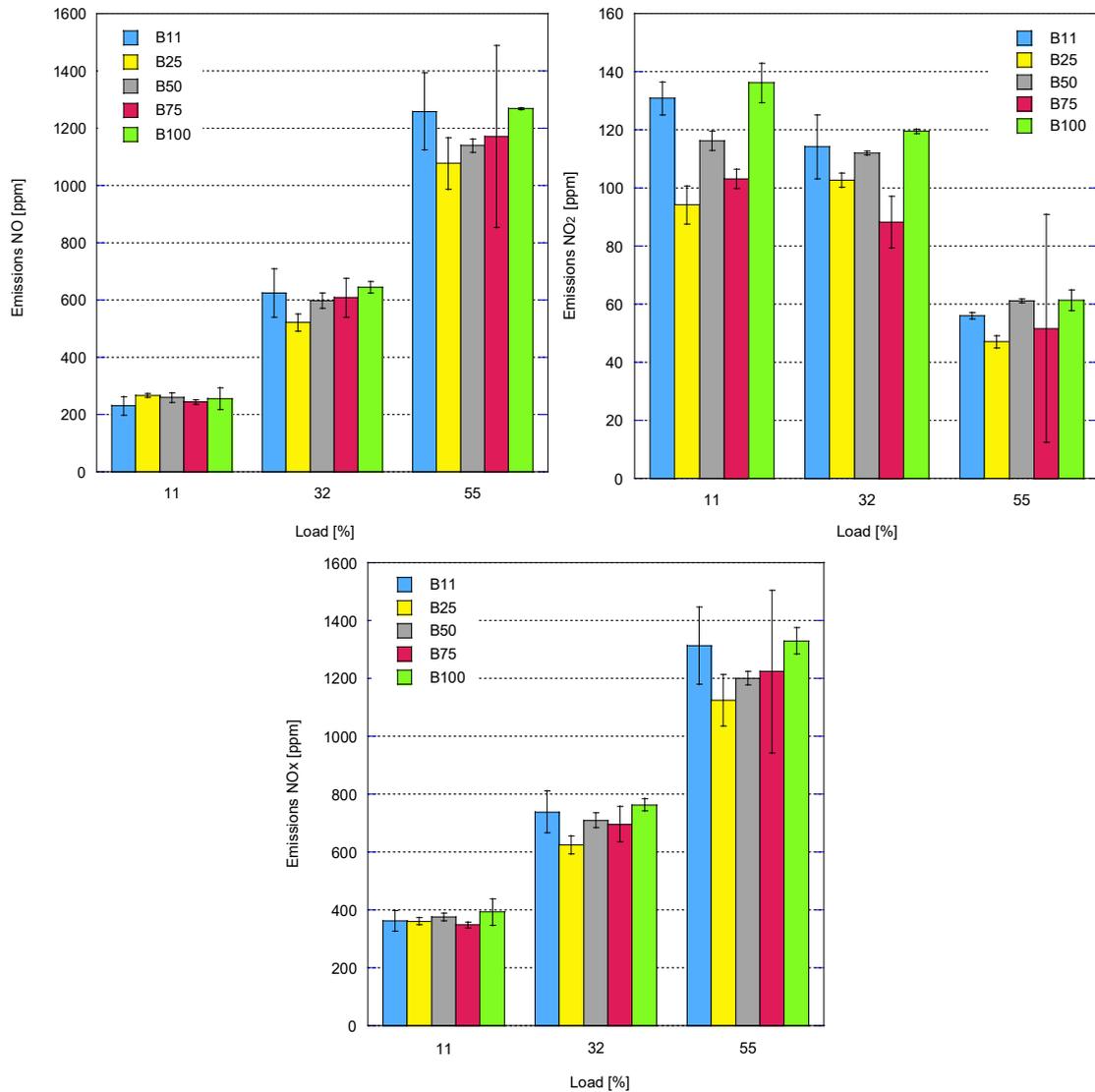
The figure 5. Emissions of NO, NO$_2$ and NO$_X$

The Figure 5, presente the emissions of nitrogen monoxide (NO), nitrogen dioxide (NO$_2$) and nitronegated oxides (NO$_X$). The NO numbers is propostional of the growing the temperatura, so its happed when put more load into the engine. The NO$_2$.is decrese when put more loda So the results of NO, NO$_2$ and NO$_X$ are the expected. The NO is more representatix in NOx emissions, how we could see in the Fig. 5. Together with it, the B11 and B100 were the blends that released more pollutants from nitrogen compounds,a nd the B25 was the fuel with.the less polutants of nitrogen oxides.

With all of these results could determinded that the B25 is the best option of blends diesel/biodiesel when is analized the performance and emissions.

4. SUGGESTIONS FOR FUTURE WORKS

For future work, the following proposals are considered:

- To measuring the consumption put a more precise balance;
- To determine the 2nd law efficiency, use an equipment that can indicate heat source the temperature more near of the reality the engine, because in this study was measuring in in the engine exhaust.

5. ACKNOWLEDGMENT

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