Theoretical And Experimental Evaluation Of Co_2 Emissions From Commercial Diesel B10 And Biodiesel B100

Evaluación teórica y experimental de emiciones de Co_2 a partir de diesel comercial B10 y biodiesel B100

Avaliação teórica e experimental de emulsões de CO2 a partir de do diesel comercial B10 e do biodiesel B100

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Abstract

This article is a product of the research “Theoretical and experimental evaluation of CO_2 emissions from commercial diesel B10 and biodiesel B100”, developed at the Universidad Cooperativa de Colombia and the Universidad Mariana of Pasto, in the years 2018 and 2019.

Introduction: The Paris Summit proposed a reduction in greenhouse effect gases (GEG) by 2030. Colombia committed itself to a reduction of 20%. For this reason, and to propose sustainable energy alternatives from fossil fuel substitutes, an inventory of the CO_2 emissions of a diesel engine were made and evaluated.

Problem: The use of fossil diesel B10 and biodiesel B100 in engines creates CO_2 emissions and it is necessary to quantify them.

Objective: To quantize the CO_2 emissions from the exhaust of an engine, using B10 and B100 fuels.

Methodology: The motor of an electric power plant was subjected to three power settings. Two factors were taken into account: the type of diesel and power generated, and the effect on the CO_2 emissions.

Results: CO_2 inventories and emissions are higher with B10, although this is not always the case. They are also higher when more power is generated.

Conclusion: The higher CO_2 emission does not depend on the type of fuel, but on the chemical composition of the fuel.

Originality: In the world they are made CO_2 inventories, these are usually done theoretically; however, with this research, actual measurements were made.

Limitations: For reasons of noise and smoke hazards, the experiment was done in an open space. This would have caused slight errors in the results, due to abrupt changes in the climate and variability in the weighing of the fuel.

Key words: biodiesel; CO_2; mole fraction; emission factor; greenhouse effect gases.

Resumen

El presente artículo es producto de la investigación “Evaluación teórica y experimental de emiciones de CO_2 a partir de diesel comercial B10 y biodiesel B100”, desarrollada en Universidad Cooperativa de Colombia y Universidad Mariana de Pasto, en los años 2018 y 2019.

Introducción: La Cumbre de París propuso la reducción de gases de efecto invernadero GEI, para 2030. Colombia se comprometió a reducir el 20%. Por esta razón, y para proponer alternativas energéticas sostenibles a partir de sustitutos de combustibles fósiles, se hizo inventarios y se evaluó las emisiones de CO_2 de un motor diésel.

Problema: El uso de diésel fósil B10 y biodiésel B100 en motores, causa emisión de CO_2, y es necesario cuantificarla.

Objetivo: Cuantificar la cantidad de CO_2 emitido por tubos de escape de motores, empleando combustibles B10 y B100.

Metodología: El motor de una planta eléctrica fue sometido a demanda de tres potencias. Se hizo un diseño de dos factores: tipo de diésel y potencia generada, y se determinó el efecto en la emisión de CO_2.

Resultados: Los inventarios y las emisiones de CO_2 son mayores con B10, aunque este no es siempre el caso. También son más altos cuando se genera más potencia.

Conclusión: La mayor emisión de CO_2 no depende del tipo de combustible, sino de la composición química del mismo.

Originalidad: En el mundo se hacen inventarios de CO_2 teóricamente, en esta investigación se hizo mediciones reales.

Limitaciones: Por razones de ruido y olor a humo, el experimento se hizo en espacio abierto, lo cual habría causado leves errores en los resultados, por cambios abruptos en el clima y variabilidad en el pesaje del combustible.

Palabras claves: biodiesel, CO2; fracción molar; factor de emisión; gases de efecto invernadero.

Resumo

Este artigo é o produto da pesquisa "Avaliação teórica e experimental de emulações de CO2 do diesel comercial B10 e biodiesel B100", desenvolvida na Universidade Cooperativa da Colômbia e na Universidade Mariana de Pasto, nos anos de 2018 e 2019.

Introdução: A Cúpula de Paris propôs a redução de gases de efeito estufa até 2030. A Colômbia se comprometeu a reduzir 20%. Por esse motivo, e para propor alternativas sustentáveis de energia a partir de substitutos de combustíveis fósseis, foram feitos inventários e avaliadas as emissões de CO2 de um motor diesel.

Problema: O uso do diesel fóssil B10 e do biodiesel B100 nos motores causa a emissão de CO2 e é necessário quantificá-lo.

Objetivo: quantificar a quantidade de CO2 emitida pelos tubos de escape do motor, usando os combustíveis B10 e B100.

Metodologia: O motor de uma usina foi submetido à demanda de três potências. Foi feito um projeto de dois fatores: tipo de diesel e energia gerada, e o efeito na emissão de CO2 foi determinado.

Resultados: Os estoques e as emissões de CO2 são maiores no B10, embora esse nem sempre seja o caso. Eles também são mais altos quando mais energia é gerada.

Conclusão: A maior emissão de CO2 não depende do tipo de combustível, mas da composição química do combustível.

Originalidade: Teoricamente, são feitos inventários de CO2 no mundo, nesta investigação foram feitas medições reais.

Limitações: Por razões de ruído e cheiro de fumaça, o experimento foi realizado em espaço aberto, o que causaria pequenos erros nos resultados, devido a mudanças bruscas no clima e variabilidade na pesagem do combustível.

Palavras-chave: biodiesel, CO2; fração molar; fator de emissão; gases de efeito estufa

1. INTRODUCTION

1.1. Overview

Particles suspended in the air are dangerous to health. Those of a diameter of less than 10μm penetrate into the respiratory system, and they are related to the use of fossil fuels. Those of a diameter of less than 2.5 diameter μm penetrate into the bloodstream [1]. Chemical reactions in the atmosphere generate N_2O, CO_2, SO_2, NH_3 and other greenhouse effect gases (GEG) [2]. Emissions from the combustion of diesel can cause cancer and other diseases, using biodiesel B100 eliminates up to 90% of the toxicity presented in the air [3].

The Kyoto protocol proposed a reduction in GEG.; In 1950, the CO_2 concentration was estimated to be 275 parts per million ppm, 365 ppm for the 2000, and 393 ppm on 2012 [4]. During the last 650,000 years this number ranged between 180 ppm and 290 ppm, and in accordance with the Intergovernmental Panel for Climate Change IPCC, the critical point is located at 450 ppm [5]. The Paris Summit proposed goals for 2030 [6]. Colombia committed itself to a reduction of 20% of GEG by 2030 [7].

1.2. Background

The planning System of energy alternatives found that 1 055 000 Diesel cars from Medellín [8] emit 1 177 141 t/a CO_2 [9]. The trucks urban of Bogota, emitted 572.286 in 2015 [10] and 1 100 000 t in 2016, information obtained with the methodology of geographical and temporal distribution from the IPCC [11]. In Ibague, data obtained from the consumption of B10 in service stations in 2016, showed that 220 Gg CO_2 were emitted [12]. In 2007, trucks and buses from Pereira emitted 5 549 t/a CO_2, information obtained from the International Emissions Software Model [13]. In Pasto, 8 127 passengers/day were transported daily with 478 vehicles in the second half of 2018 [14], and it is expected that consumption rates will rise to 177 046 Barrels per Calendar Day (BCD) of diesel for the year 2020 and 251 817 BCD by 2035 [15].

In 2020, Colombia will have 3 500 000 vehicles [16]; in August 2017, 127 thousand BCD/month of diesel fuel were sold [17]; and in 2020, freight, intercity passenger, and urban public transport will have emitted 128 million t CO_2 [18].

In 2015, Guanacaste park in Panama and Costa Rica emitted 21.81 t/day CO_2 [19], vehicles diesel issued 58.1 t CO_2, data obtained with emission factors from the National Meteorological institute [20]. In 2011, "El Canton", San José of Costa Rica received 283 730 t CO_2; information obtained from the fuel consumption of buses and trucks [21]. The public transport from Paraná and Brazil emitted 200 000 t CO_2, results obtained with tests of opacity [22]. Between 2000 and 2012, Brazil emitted 10 497 733 t CO_2 from diesel fuel used in tractors for the production of 41 crops [23]. Guayaquil issued 193 945 t CO_2 with heavy cargo vehicles [24].

Mexico, with eight million diesel operated trucks and buses, emits over 400 million t/a CO_2. Nuevo Laredo, Mexico, emits 11 562.6 t/day CO_2, using figures estimated using the IPCC methodology [25], and by the year 2050, 19% of emissions will have originated from transport trucks, tractor-trucks and buses [26].

America, without the U.S.A, emits 972 million t/a CO_2 [27]. In Latin America and the Caribbean during 2009, among the 50 largest emitters of CO_2 from diesel and gasoline, Mexico was 13th, Brazil 17th, Venezuela 27th, Argentina 28th, Colombia 44th, with 459, 374, 190, 179, and 75 million t/a CO_2 respectively [28].

Ottawa, emitted between 0.6 and 3.7 t/a CO_2, from vehicle models 1997 to 2004 [29]. Madrid, emitted 3.730 t/a CO_2, using data obtained by the methodology of amount of systems in emissions of basic security [30]. In Tehran, urban transport frees up 10 million t/a CO_2 [31].

The Environmental Protection Agency EPA of the USA, measures the overall emissions from the fuel mass consumed, the emission factor EF, and the overall efficiency of emissions reduction of CO_2 [32].

2. METHODOLOGY

2.1. Methodological design

A power plant of 2.5 kW was subjected to different power generation levels, as shown by Simmons [33]. 24 mole fraction data was obtained, which is multiplied by the fuel consumption. This result corresponds to the CO_2 emitted.

The present investigation resembles a factorial design, considering two factors: type of fuel with two levels B10 and B100; and work done at three power levels: 0.5kW-1.0kW-1.5kW. The joint effect that these factors produced on the response variable was studied. To obtain a robust measurement of the effects of the factors, four replications were made, therefore 24 observations were generated. The response variables are: the mass of CO_2 emitted in each combination and the CO_2 emission factor of commercial diesel B10 and biodiesel B100. An ANOVA model is presented with factorial design of fixed effects and two factors: fuel and power generated [34].

2.2. Materials and methods

The electric generator is characterized as per [35]: GPMD diesel reference, 2.5 kW, with 7HP motor. A PCE PEC 007 anemometer was adapted to the engine's intake air tube to measure mass flow. A flexible hose of equal diameter to the anemometer was connected to the engine air intake system. In this way the m/s of incoming air was measured and converted to kg of air/minute. Similarly, a hose was connected to the neck of a funnel and inserted directly into the engine's fuel supply.

Data of relative humidity, temperature and atmospheric pressure of the city of Pasto were used, provided by the Institute of Hydrology, Meteorology and Environmental Studies IDEAM Colombia; the partial pressure of the water vapor was calculated, and with this data, the stoichiometric coefficient or mole fraction of the water vapor in the air X_{H2O} was obtained.

The mole fraction of water vapor in air X_{H2O} was calculated. The moisture content of the intake air n, necessary for the calculation of the mole fraction or CO_2 emission factor of the combustion process, was determined as shown in Formula 1 [36].

(Formula 1)

$$\%Vol_{CO_2} = 100 * X_{CO_2} = 100 \frac{a}{\frac{b}{4}+\lambda(4{,}773+n)\left(a+\frac{b}{4}-\frac{c}{2}\right)+\frac{c}{2}}$$

Where;
a: content of C
b: content of H
c: content of O
n: intake air humidity
λ: air/fuel relationship

The fuel hose was purged. With the method of described in [37], the experiment was carried out with each fuel, starting with 0.5kW and gradually working up to 1.5kW. In each treatment, with commercial diesel B10 and biodiesel B100, four runs were made, one for each of the three levels of electricity generation measured in kW. 100 grams of each fuel was used in each run.

The mixer and manufacturer companies, in Colombia, with gas chromatography indicated that each mole of B10 contains 53.54% C, 46.11% H and 0.34% O [38]; and each mole of B100 contains 32.84% C, 63.52% H and 3.6% O [39].

3. RESULTS

Table 1 presents atmospheric data and results for each combination: the relative relationship air/fuel λ, mole fraction, work performed, EF CO_2, and a kg of CO_2 emitted, in ml, g and ppm, in each repetition, fuel and power.

Table 1. Data and Results for the mole fraction or EF calculated.

B10 COMERCIAL DIESEL	FIRST RUN			SECOND RUN			THIRD RUN			FORTH RUN			Average
Power (kW)	0.5	1.0	1.5	0.5	1.0	1.5	0.5	1.0	1.5	0.5	1.0	1.5	
Temperature (°C)	18.08	17.10	17.10	15.14	17.30	18.08	16.60	16.91	15.53	21.43	20.25	20.05	17.80
Duration (min)	15.53	12.89	9.60	15.67	12.70	9.79	15.52	12.50	9.44	15.76	12.94	9.58	12.66
Relative Humidity (%)	57%	57%	57%	57%	57%	57%	88%	88%	88%	88%	88%	88%	73%
Pressure (hPa)	820.86	820.86	820.86	820.86	820.86	820.86	817.81	817.81	817.81	817.81	817.81	817.81	819.34
Relation λ=	1.38	1.14	0.82	1.42	1.11	0.85	1.42	1.11	0.82	1.39	1.15	0.82	1.12
Mole Fraction CO_2=	0.12	0.15	0.20	0.12	0.15	0.19	0.12	0.15	0.20	0.12	0.14	0.20	0.16
Work Done (J)=	465 980	773 240	864 300	470 150	761 930	881 520	465 480	750 170	849 465	472 865	776 430	862 005	699 461
IPCC Emission Factor =	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96
CO_2 emitted (g) IPCC=	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO_2 emission (ml)=	193.56	194.78	199.02	191.49	195.16	199.19	192.15	194.94	198.06	195.30	196.31	200.62	195.88
CO_2 emission (g)=	0.36	0.36	0.37	0.35	0.36	0.37	0.35	0.36	0.36	0.36	0.36	0.37	0.36
Emission (CO_2 mg/diésel gr)=	3.57	3.59	3.67	3.53	3.59	3.67	3.54	3.59	3.65	3.60	3.62	3.70	3.61
Emission (ppm)=	121 321	146 518	201 505	118 597	149 616	194 521	117 799	150 225	201 376	119 816	144 368	200 433	155 508
BIODIESEL B100	FIRST RUN			SECOND RUN			THIRD RUN			FOURTH RUN			Average
Power (kW)	0.5	1.0	1.5	0.5	1.0	1.5	0.5	1.0	1.5	0.5	1.0	1.5	
Temperature (°C)	26.15	24.38	22.61	21.82	19.26	18.28	17.50	18.48	19.07	22.61	20.64	15.73	20.54
Duration (min)	15.10	12.19	8.77	15.20	11.83	9.01	15.09	12.36	9.51	15.46	12.43	9.64	12.21
Relative Humiduty (%)	32%	32%	32%	32%	32%	32%	32%	32%	32%	32%	32%	32%	32%
Pressure (hPa)	818.49	818.49	818.49	818.49	818.49	818.49	818.49	818.49	818.49	818.49	818.49	818.49	818.49
Relation λ=	1.25	1.00	0.71	1.29	0.99	0.74	1.29	1.03	0.78	1.32	1.04	0.81	1.02
CO_2 Mole fraction=	0.11	0.14	0.19	0.11	0.14	0.18	0.11	0.13	0.17	0.10	0.13	0.16	0.14
Work Done (J)=	452 880	731 560	788 925	455 880	709 850	810 975	452 640	741 460	855 810	463 670	745 740	867 300	673 058
IPCC Factor Emission=	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31
CO_2 emitted (g) IPCC=	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO_2 Emission (ml)=	170.24	169.97	170.35	167.83	167.35	167.99	165.55	166.84	168.11	168.28	167.81	166.30	168.05
CO_2 Emission (gr)=	0.31	0.31	0.31	0.31	0.31	0.31	0.30	0.31	0.31	0.31	0.31	0.31	0.31
Emission (CO_2 mg/biodiesel gr)=	3.14	3.13	3.14	3.09	3.08	3.09	3.05	3.07	3.10	3.10	3.09	3.06	3.10
Emission (ppm)	109 882	135 843	185 282	107 050	136 877	178 712	106 767	131 410	169 642	104 613	130 811	164 906	138 483

Source: own work. Data obtained from the experiment and figures from the actual research.

It is observed that, when generating greater power, the mole fraction of CO_2 is greater (see Figure 1). According to the results of the air/fuel ratio λ, it can be affirmed that, having higher values of λ, biodiesel B10 has combustion with excess oxygen; a desired situation according to the theoretical support. It can also be inferred that as the demand for power increases, the emission factor or mole fraction of CO_2 increases.

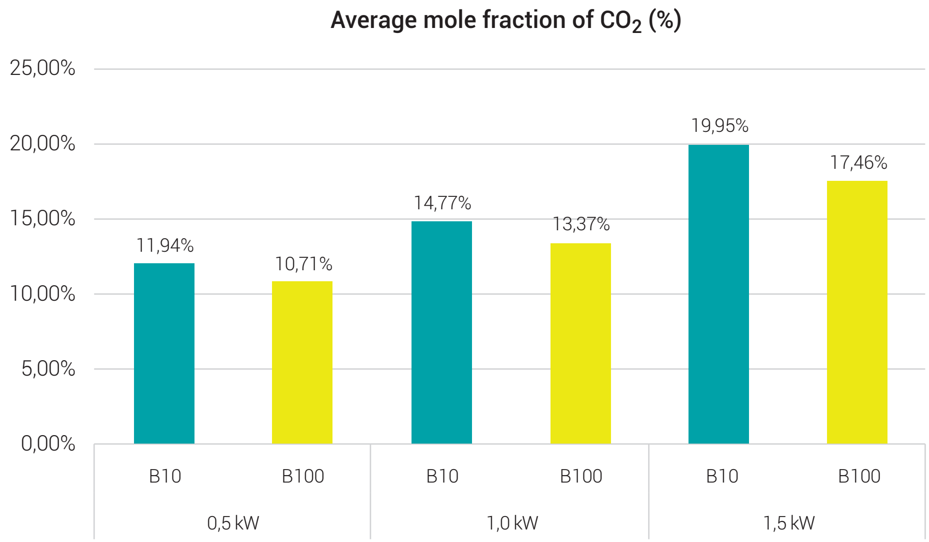

Figure 1. Mole fraction with three generated powers and two fuels used
Source: own work

Generating the same power, the duration of commercial diesel B10 is longer than that of biodiesel B100, therefore, with the use of equal amounts in grams of fuel in different repetitions, the commercial diesel analyzed can do more work than the analyzed biodiesel (see *Figure* 2), for having greater volume in the same weight, 117.2 ml with respect to 114.5 ml.

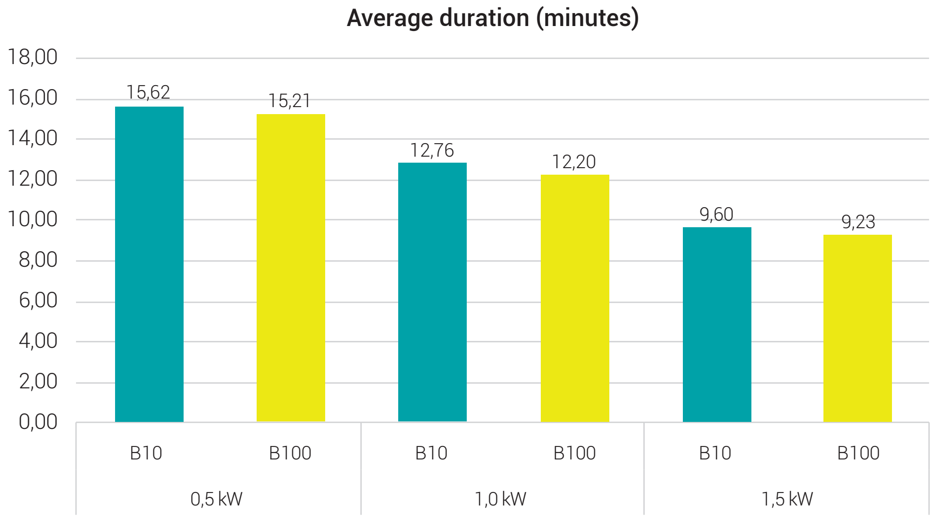

Figure 2. Average duration of fuels
Source: own work

By generating more power, CO_2 emission increases; with B100 the CO_2 emission is lower (Figure 3). With Fisher´s method and 95% reliability, the multiple range test indicates that the CO_2 emission, in volume and weight, is greater with B10 fuel.

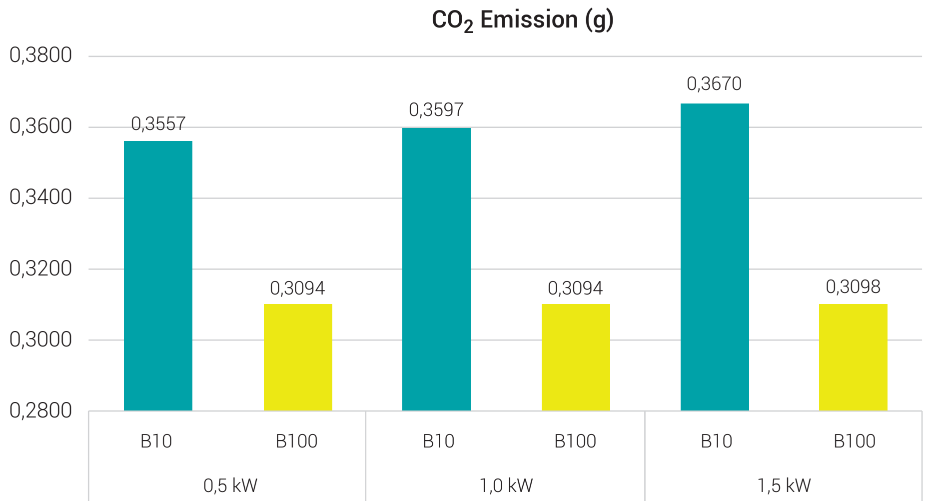

Figure 3. CO_2 emission from B10 and B100
Source: own work

There is an inverse correlation between the relative air/fuel ratio λ and the CO_2 mole fraction greater than 99% and 98% in treatments with B10 and B100 respectively, and this relationship describes a second order polynomial behavior. With a high degree of certainty, the higher the air / fuel ratio, the lower the emission factor, or vice versa (see Figure 4); however, it does not mean that the fuel of greater λ has a lower emission factor, since this also depends on the molecular composition of the fuel.

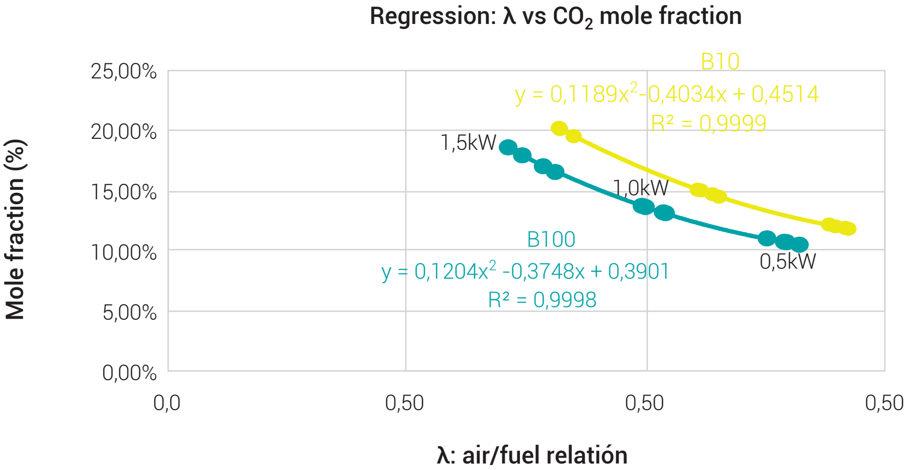

Figure 4. Influence of the λ on the mole fraction o EF
Source: own work

There are also second order polynomial models in relation to the variables Work performed and Mole fraction, with the use of the two fuels. The mole Fraction explains the work performed in 96% and 81% with B10 and B100 respectively (Figure 5).

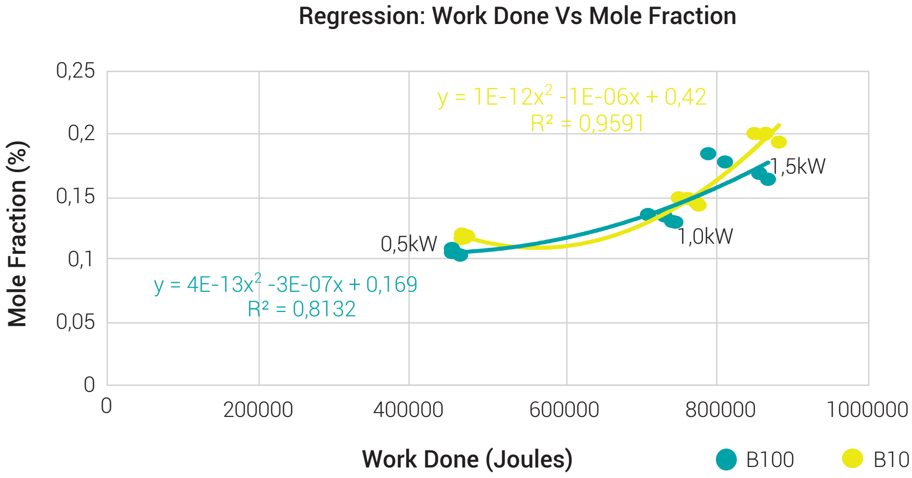

Figure 5. Influence of the Work performed on the mole Fraction
Source: own work

4. DISCUSSION

There are differences in the CO_2 estimates, of: Gutierrez, 2.6 kg/l [40]; IPCC 20.200 g/GJ [41]; Orovio, 28 g/l - km [42]; and of the current research, 4,15 g/l with B10. When you apply the EF of IPCC methodology tier two [43], the emissions have low values compared with the experiment's results.

The EF of EPA-USA, is 1.15 per lb of diesel used in each HP-h [44]. Thus, to generate the seven horsepower of the engine, during 12.6 min average, with 100 g of diesel, they emit 1.298 g of CO_2: three times the average emission obtained, 0.361 g of CO_2 (Table 1). That is the methodology with results more similar to those of this experiment.

In production, transportation and marketing, B10 and B100 emit similar amounts of CO_2, but the plants in order to obtain oil as a raw material for B100, consume considerable amounts of CO_2 [45].

UpTown Oil of Paris believes that replacing diesel with B100, obtained from used cooking oil UCO, saves 80% CO_2 emissions [46]. On the contrary, Ulusoy, cited by Enweremaduen, explains that it increases emissions by 2.6% [47]. The Department of Energy of USA, says that the B100 produced with soy emits 2.661 g CO_2/gal and diesel 12.360 g CO_2/gal [48]. Dorado explains that B100 emits 8.6% less CO_2 [49]. It was observed in Washington that an engine running at 3 000 rpm, decreased CO_2 by 10% when using B100 [50], and according to Chang, the higher concentration of CO_2 was found in the blend B50 at all rpm [51]. The present experiment managed to save less than 10% of CO_2 emissions when using B100 instead of B10.

5. CONCLUSIONS

It is important to achieve mixtures with a lower carbon levels. Even if the content of hydrogen and oxygen increases, the CO_2 emission is lower.

The emission of CO_2 has a correlation of 97% with the amount of fuel consumed. Thus, it is not associated with the mileage, taking into account the inclinations of the roads. In the same volume, B10, and B100, are consumed at the same rate.

Global CO_2 emissions would be reduced if B10 fuel is replaced by B100. This reduction will be added to the minimization achieved in the process of obtaining B100 in the replacement of the B10 process.

To achieve the goals of the Kyoto protocol, the Paris Summit, and meet the demand of B100, UCO should be recycled to obtain B100, with environmental, economic and social benefits of large impact.

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