PRODUCTION CHARACTERIZATION AND TESTING OF SOYBEAN BIODIESEL IN A DIESEL CYCLE ENGINE

S. C. P. Gonçalves[a],
M. C. L. Souza[b],
J. T. Assis[c]
J. C. C. Egúsquiza[d],
S. L. Braga[d]
and N. C. O. Tapanes[b]

[a]PPG-EM/UERJ/RJ
[b]Centro Universitário Estadual da Zona Oeste
Engineering School
Av. Manuel Caldeira de Alvarenga, 1203, Rio de Janeiro - RJ, 23070-200, Brasil
maurosouza@uezo.edu.br
[c]Instituto Politécnico da UERJ/RJ
[d]ITUC/PUC/RJ

Received: Nov 03, 2021
Revised: Dec 02, 2021
Accepted: Dec 17, 2021

ABSTRACT

The characteristics of the biodiesel produced by the transesterification reaction of soybean oil with anhydrous ethanol, catalyzed by sodium hydroxide and its thermo-oxidative stability, were investigated by thermal analysis and viscosity. It was analyzed density at 20 °C, sulfur content, cetane number, carbon residue, iodine index, acidity, sulphated ash, the total content of glycerin and unreacted fatty acids. The synthesis of biodiesel via ethanolic processed in a Pyrex glass reactor with 2/1 molar ratio triglyceride/anhy-drous ethanol and 1% of catalyst, 60 °C. After the reaction, the phases were separated and glycerin was removed. The biodiesel was washed with 0.1M HCl solution, at ~ 70 oC for neutralization. The physicochemical analysis, all parameters for biodiesel met the requirements of the ANP Technical Standards. From the produced biodiesel, binary mixtures were made with diesel in the proportions of 2, 5, 10, 15, 20 and 30%. The objective was to study the behavior of mixtures in a diesel cycle engine coupled to a dynamometer of Eddy Current. In this study of burning biodiesel blends in diesel engine were analyzed and compared with pure diesel parameters: consumption, efficiency, performance, torque and power. The results showed that the mixtures had very similar properties and performance to pure diesel by mixing 20%. To the mixture with 30% there has been a significant drop in torque and power and slight increase in consumption. Thus, it was shown that soybean oil biodiesel, mixtures of 2% to 30%, is applicable as an alternative fuel aptly, for the diesel cycle engines, because it is a renewable and environmentally friendly fuel.

Keywords: soybean oil biodiesel; blends biodiesel/diesel; dynamometric testing bench

NOMENCLATURE

ANP – National Petroleum Agency
PPG-EM – Postgraduate Program of Mechanical Engineering.

INTRODUCTION

The main factors that determine the raw material of greatest interest for the production of biofuels, in addition to the economy of each country, are geography and climate. European and Canadian producers depend on rapeseed oil, which corresponds to 65% of the raw material they use to produce biofuels; other oleaginous sources are soy, canola and palm oil. European producers depend on rapeseed oil, which corresponds to 65% of the raw material they use to produce biofuels; other oleaginous sources are soy, canola and palm oil (S&P GLOBAL PLATTS, 2021). Across Asia, the main raw material for producing biodiesel from biomass (BBD) is palm oil. In the United States, half of biodiesel production comes from soybean oil and the other half comes from other raw materials, such as recycled cooking oil and animal fats (GZH, 2016; Biodieselbr, 2021).

Brazil, due to its large plantation areas, an adequate geography and a favorable climate, is capable of producing a wide variety of oilseeds that can be used in the production of Biodiesel. Data exposed by the ANP show that Brazilian biodiesel has its largest share of raw material in soybean oil, with approximately 71%, with the remainder coming from beef tallow and, to a lesser extent, other oils such as sunflower, cotton and palm (S&P GLOBAL PLATTS, 2021).

The consequences of the Covid 19 pandemic affected the global energy market, including the production and consumption of biodiesel. However, in 2020, more than 6 billion liters of biodiesel were consumed in Brazil, which represents an increase of about 10% compared to 2019. The percentage of mandatory addition of biodiesel to the fossil diesel mixture was raised to 12 % in March 2020, as provided for in CNPE Resolution 16/2018 (MME, 2018). In March 2021, the National Energy Policy Council (CNPE) authorized the increase to 13%, and due to logistical problems, this value was reduced to 10% in September. Since the beginning of the National Program for the Production and Use of Biodiesel (PNPB) in 2005 until December 2020, more than 47 billion liters of this biofuel were produced (EPE, 2021). Brazil remains among the three largest producers and consumers of biodiesel in the international ranking, after Indonesia and the USA.

In this context, the present paper aims to characterize the soybean biodiesel produced from transesterification with anhydrous ethanol (catalyzed with NaOH), according to ANP specifications and evaluate the performance through tests in a Diesel Cycle Engine coupled to an Eddy Current Dynamometer.

MATERIAL AND METHODS

Filtered Soybean Oil, obtained from the market, was transesterified in a Pyrex glass reactor, with a capacity of 6 l. The reactor, instrumented with a mechanical stirrer, with variable speed, temperature gauge and heating blanket, was installed in a hood in the PPG-EM laboratory at GESAR/UERJ, as shown in Figure 1. The system was initially heated to 50°C. Then 3 liters of neutral soybean oil was added. When the oil temperature, inside the reactor, reached 45°C, a solution of 1.5 l of anhydrous ethanol + 15 g of NaOH catalyst was added, establishing, at that moment, the initial time of the reaction. (SCHUCHARDT, 2006; BUNYAKIAT, 2006).

The reaction time was 60 minutes, verified through the sudden darkening and subsequent lightening of the content. After the end of the reaction, about 600 ml of glycerin was added to facilitate the formation of the lower phase.

The contents of the reactor were transferred to a 5l beaker and, after about 24 hours, there was a complete separation of the two phases: Ethyl Esters (on top) + glycerin with excess ethanol, soap residues and sodium hydroxide, which did not react (at the bottom).

The upper phase, composed of a mixture of ethyl esters of fatty acids (Biodiesel), was separated and neutralized by washing with a solution of 1.5 l of distilled water, at 90°C and 0.5% of concentrated HCl. Biodiesel was separated from the aqueous phase and moisture removed by filtration with anhydrous $NaSO_4$.

The physicochemical analyzes of Biodiesel regarding: color, appearance, specific gravity at 20°C, sulfur content, cetane index, carbon residue, diesel miscibility were performed at the EQ/UFRJ Biodiesel Laboratory, according to the recommended methodologies by the ANP (SCABIO et al., 2005).

Figure 1. Soybean Oil Transesterification Reaction.

The Biodiesel produced was tested in a Diesel Engine 145 HP MWM 4.1, coupled to an Eddy Current Dynamometer, at the Vehicle Engineering Laboratory at PUC-RIO, as shown in Figure 2 (SANTOS, et al., 2006).

Figure 2. Dynamometer Coupled Diesel Engine.

RESULTS AND DISCUSSION

The results of the chromatographic analyzes of the produced Biodiesel are shown in Table 1. The physicochemical parameters and characteristics presented very reasonable results for most of the analyzed characteristics.

Table 1. Characteristics of produced biodiesel.

Characteristics	Results	ANP Resol. 42/2004	
Appearance	LII	-	LII
Specific mass at 20ºC	887,2 kg/m³	875	900
Total sulfur	0,0002 % m/m	-	0,075
Cetane number	58	57	62
Carbon residue	0,05 %% m/m	-	0,1
Iodine index	116	-	<115
Acidity index	0,92 mg KOH/g	-	0,8
Sulphated ash	0,012 % m/m	-	0,02
Total Glycerin	0,48 % m/m	-	0,38
Ester Content	86 % m/m	85	100

* Speed min (cm/min)

Some characteristics, such as carbon residue, appearance, sulfated ash, cetane number and total sulfur, were excellent, beyond expectations. Specifically, the higher number of cetane and the lower sulfur content in biodiesel, compared to diesel, are the main advantages that enhance the use of the mixture (ROCHA, 2014)

The acidity index slightly above specifications is credited to a normal amount of non-transesterified fatty acids and is considered within the normal range, not causing problems in the use of biodiesel. An ideal Biodiesel has an ester content above 90%. The result obtained was due to a non-complete transesterification.

Dynamometric Testing Bench

Figures 3, 4 and 5, below, show, respectively, the results of Consumption, Power and Torque, for the various mixtures used and different engine speeds.

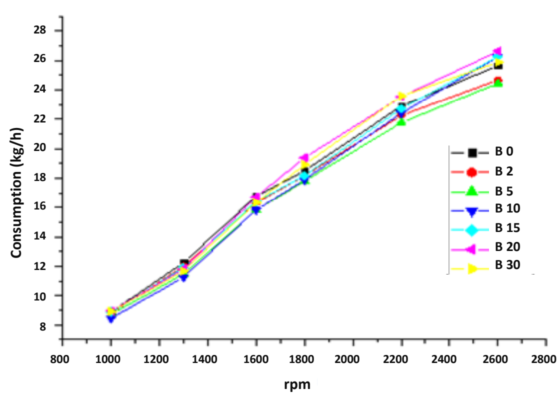

Figure 3. Consumption curves

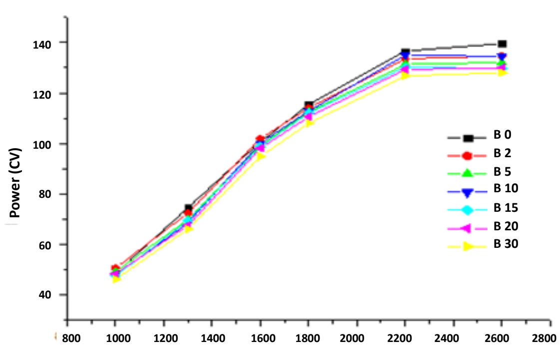

Figure 4. Power curves

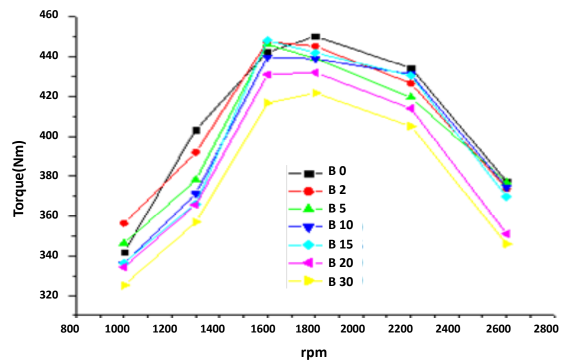

Figure 5. Torque curves

CONCLUSIONS

The 86% yield in the soybean oil transesterification to produce biodiesel was attributed to ethanol impurities. Previous analysis of this revealed the presence of dyes and traces of moisture. Even so, the result was within the established by the ANP. With pure reagents, the yield can reach 97%.

A total loss of around 10% was found, attributed to the process of recovering ethanol and glycerin, by distillation. Nevertheless, the process is economically viable, considering that Biodiesel is a renewable fuel. With less loss, the process is more profitable.

The physical-chemical analyzes showed that the quality of the biodiesel was very close to the ANP standards. The sulfur and ash content, among others, showed much lower values.

When tested in the Diesel Engine, blends with certain levels of biodiesel (eg 20%) showed that consumption even decreases when compared to pure diesel. The Consumption, Power and Torque results of the present work are in accordance with all the consulted literature.

Considering that Biodiesel is a fuel obtained from Renewable Sources and these raw materials are abundant in Brazil, the continuity of production and the increase in the addition of biodiesel in Fossil Diesel is highly recommended. The economy is relevant. The generation of jobs in the sector must also be considered.

The commercial/industrial scale production of Biodiesel certainly generates a considerable reduction in the dependence on Diesel, which Brazil still imports, in appreciable quantities.

Reducing the emission of sulfur dioxide (SO2), particulate matter (PM) and carbon monoxide (CO) and other diesel pollutants into the atmosphere is very relevant and should also be considered.

ACKNOWLEDGEMENTS

The authors would like to thank the financial support given by the Research Support Foundation of the State of Rio de Janeiro (FAPERJ) to the study.

REFERENCES

ANP, 2021, *Anuário Estatístico.* Available in: https://www.gov.br/anp/pt-br/centrais-de-conteudo/publicacoes/anuario-estatistico/anuario-estatistico-2021. Access Date: 10 oct. 2021.

BiodieselBr, 2011, *As matérias-primas utilizadas pela Europa no biodiesel*. Available in: https://www.biodieselbr.com/noticias/bio/materias-primas-utilizadas-europa-biodiesel-060411. Access Date: 14 oct. 2021.

Bunyakiat, K., Makmee, S., Sawangkeaw, R., Ngamprasertsith, S., 2006, Continuous Production of Biodiesel via Transesterification from Vegetable Oils in Supercritical Methanol. *Energy Fuels*, 20(2), 812-817. https://doi.org/10.1021/ef050329b

EPE Empresa de Pesquisa Energética, 2021, *Análise de Conjuntura dos Biocombustíveis – Ano 2020. NOTA TÉCNICA EPE/DPG/SDB/2021/03.* Available in: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-615/NT-EPE-DPG-SDB-2021-03_Analise_de_Conjuntura_dos_Biocombustiveis_ano_2020.pdf. Access Date: 15 oct. 2021.

GZH, 2016, *Nos Estados Unidos, biodiesel é utilizado em misturas que vão de 2% a 100%: Entrevista Kaleb Little, gerente do Conselho Nacional do Biodiesel (NBB) nos Estados Unidos.* Available in: https://gauchazh.clicrbs.com.br/economia/campo-e-lavoura/noticia/2016/04/nos-estados-unidos-biodiesel-e-utilizado-em-misturas-que-vao-de-2-a-100-5754208.html. Access Date: 15 oct. 2021.

MME. Resolução CNPE n° 16, de 29 de outubro de 2018. *Dispõe sobre a evolução da adição obrigatória de biodiesel ao óleo diesel vendido ao consumidor final, em qualquer parte do território nacional. Conselho Nacional de Politica Energética.* Brasília: Diário Oficial da União. Available in: www.mme.gov.br/documents/10584/71068545/Resolucao_16_CNPE_29-10-18.pdf. Access Date: 14 oct. 2021.

Rocha, H. L., Pinto, N. R., Colaço, M. J., Leiroz, A. J. K., 2014, Experimental study of ternary fuel blends on an ASTM-CFR-CETANE engine. Journal of Thermal Engineering, 13(2), 9-15, http://dx.doi.org/10.5380/reterm.v13i2.62087

Santos, D. C., Alves, C. T., Torres, E. A., Nóbrega, S. D., 2006, Comparação de Desempenho de um Motor Monocilindro do Ciclo Diesel Operando com Diesel e Biodiesel (B100). *3° Congresso Brasileiro de Plantas Oleaginosas, Óleos, Gorduras e Biodiesel, Anais*, 988-992.

Scabio, A; Ferrari, R. A.; Oliveira, V. da S. G., 2005, Biodiesel de soja Taxa de conversão em ésteres etílicos, caracterização físico-químico e consumo em gerador de energia. *Química Nova*, 28(1), 19-23. https://doi.org/10.1590/S0100-40422005000100004

Schuchardt, U.; Garcia, C. M.; Marciniuk, L. L.; Muterle, R. B. Processo de produção de biodiesel a partir de óleos e gorduras vegetais ou animais com ou sem ácidos graxos livres utilizando catalisadores sólidos a base de fósforo e metais trivalentes, Pedido de Patente PI 10600105-0, depositada no INPI em 13/01/2006. 2006.

S&P Global Platts, 2021, *Contribuição para o programa Abastece Brasil Subcomitê Novo Cenário Downstream - Comercialização de Biodiesel*. Available in: https://www.gov.br/mme/pt-br/assuntos/secretarias/petroleo-gas-natural-e-biocombustiveis/abastece-brasil/subcomites/SPGlobalPlattsBiodiesel.pdf. Access Date: 10 oct 2021.