

Performance and Emission Characteristics of Rice Bran Oil in an Oil Burner

Burhani M Burhani¹, Mohammad N M Jaafar¹, Norazila B Othman^{1,2}, Anis A M Azli¹, Mazlan Said¹, Muhammad R Rahim¹, Muhammad S A Malik¹ and Wan Z W Omar¹

¹School of Mechanical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, Johor Bahru 81310, Johor, Malaysia

Abstract. The fossil fuels have been the most practical way to produce energy for industries, vehicles and homes due to their lower prices, good combustion properties and their availability compared to other types of fuels. However, in this era of modernization, one of the biggest challenges of humanity is depletion of fossil fuels may result the increasing of the price. Studies have found out that it is possible to improve physical and chemical characteristics of alternative fuel based biodiesel by using the transesterification process and hence act as an alternative to mineral diesel. Therefore, the study about the potentiality of the rice bran oil as biodiesel feedstock is explained in this paper. The aim of this study is determining the performance and emission characteristics of the rice bran oil biodiesel (RBOBD). In addition, the comparison is made for its combustion and emission characteristics to those of conventional diesel fuel (CDF). Results show that RBOBD is very good at minimizing emissions, especially CO and SO₂ with the value 60 ppm and 10 ppm, respectively. The establish information may help Malaysia to recognize the potentiality of the rice bran oil in order to replace the conventional fuel in the future.

Keywords: Rice bran oil; Biodiesel emission; Combustion; Nitrogen oxide; Oil Burner; Equivalence ratio

² Corresponding author. Tel.: +6-012-7136944.
E-mail address:norazila@mail.fkm.utm.my



1. Introduction

Fossil fuels have been the most practical way to produce energy for industries, vehicles and homes due to their lower prices, good combustion properties and their availability compared to other types of fuels [1].

However, decrease in oil in petroleum reserves, increasing number of vehicles, fluctuating fuel prices, uncertainties concerning petroleum availability, strict emission regulations on global warming due to carbon dioxide emissions, have forced the development of alternate fuels [2]. Studies have found out that it is possible to improve physical and chemical characteristics of biodiesel by transesterification process and hence act as an alternative to mineral diesel [3-5].

However, biodiesel's properties such as kinematic viscosity, density and calorific value, do not resemble with mineral diesel even after transesterification process. Therefore, it is preferred to blend biodiesel with diesel at certain percentages [6]. Biodiesel blends are labeled in the form of "BXX" where "B" stands for biodiesel and "XX" shows its blend percentages for example "B20" indicates 20% of biodiesel is blended with 80% of diesel. Biodiesel is a petroleum based fuel which is produced from animal fat or vegetable oil i.e. palm oil, coconut oil etc. [7-8]. One of the potential sources of this biodiesel is Rice Bran Oil (RBO). It is also a vegetable oil which is extracted from Rice Bran [9].

The physical properties of the Rice Bran Oil are very important in order to compare the biodiesel with the mineral diesel. Studies conducted by Senthilet. al. [10] and Ahmad et. al. [11] have shown that the proportion of Rice Bran Oil Biodiesel (RBOBD) increases in diesel, the kinematic viscosity increases abruptly, thus, viscosity of B100 was found to be six times higher than Conventional Diesel Fuel (CDF). It was also found that RBOBD blends possessed higher density than of diesel with the density of B100 being 7.6% higher than CDF. Also as the percentage of RBOBD in the diesel increases, studies show that the specific gravity increases with B100 showing the highest specific gravity of 0.875 compared to 0.81 of CDF – an increase of about 8% [12].

Another important physical property of the Rice Bran Oil Biodiesel is the kinematic viscosity. The kinematic viscosity is a measure of the resistance of the fuel to flow. It has effects on the performance of fuel pumps, the atomization of injected fuel, lubricity and the impinging distance upon injection. In general, biodiesel has a higher viscosity than diesel, and thus exhibit inferior atomization and spray characteristics, which results in a larger mean liquid droplet diameter and a longer ignition delay of the fuel. When viscosity is very high, it makes atomization more difficult, it affects combustion efficiency, lower the performance of fuel pumps and adversely affect exhaust emissions because of incomplete combustion [13]. The kinematic viscosity of the B100 RBOBD at 40°C has been found to be 4.52mm²/s, and although slightly higher than that of diesel (3.55mm²/s), it is within the ASTM limits for biodiesel [14]. This shows that as the percentage of the biodiesel increase in the blend, the kinematic viscosity increases.

In addition, the heating value of the biodiesel is utmost important. This is the amount of heat that can be liberated from a kg of the fuel. Heating value affects the engine power output, thermal efficiency, fuel consumption, exhaust emissions, cleanliness of the engine, time between service and vehicle performance. For B100 RBOBD the value of calorific

value is 40.3 kJ/(kg.K) while for the mineral diesel or CDF it is 44.8 kJ/(kg.K), which means RBOBD has a lower calorific value than the CDF [15]. The study also shows that the percentage of RBO increase in the blend, the calorific value increases. Therefore, due to the benefit of alternative fuel and sources from rice bran oil, it gives motivation for this study to explore in details. The intention of this study is about the determination of the characteristics of rice bran oil in an oil burner. From the investigation of rice bran oil characteristics, the performance of this feedstock can be tested. The reduction of the emission gases also can be determined. It will help Malaysia to replace the usage of fossil oil in the future.

2. Methodology

In this study, the rice bran oil was made using transesterification process to improve their properties. The RBOBD blends were prepared in the Combustion Laboratory, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia as shown in Table 1. RBOBD was blended with diesel to obtain B10, B20 and B30. The physical properties such as density at 150°C, kinematic viscosity at 40°C and gross calorific value of each RBOBD blend and diesel were tested at the Faculty of Chemical Engineering, Universiti Teknologi Malaysia.

Table 1. Physical properties of diesel and RBOBD blends

Physical property	B0 (Diesel)	B10	B20	B30	B100
Density (g/cm ³)	0.832	0.83392	0.83551	0.8371	0.884
Specific gravity	0.838	0.845	0.849	0.8535	0.899
Kinematic viscosity at 40°C (mm ² /s)	3.57	3.68	3.76	3.87	4.58
Gross calorific value (kJ/ (kg. K))	45.8	45.2	44.8	44.1	41.1

The experimental setup for combustion performance tests included an Industrial Light Oil Burner, K-type thermocouples, a standard spray nozzle, 1m cast cement insulated open-ended combustion chamber, a Midi temperature data logger, the LCA 6000 airspeed indicator and the Horiba Enda 5000 gas analyzer. The oil burner was attached at the inlet of the combustion chamber to blow air and ignite the fuel. Eight equal distant (100mm apart) thermocouples were mounted on the combustion chamber. K-type thermocouples were connected to the Midi Temperature data logger to display the wall temperature in Celsius (°C). The standard nozzle was fixed to spray the fuel inside the combustor. The nozzle sprays fuel with the pressure of 6.8 bar and the flow rate of 5.68L/h are used based on standard that provided from fuel pump series BS799: Part 2: 1981. Figure 1 shows the schematic diagram of the experimental setup while Figure 2 shows the photograph of the open-ended combustion chamber.

The emission chamber was connected to the exhaust part of the combustion chamber which had the emission sensors to detect the emissions from the combustor. Horiba Enda 5000 gas analyser then receives the electrical signal from the emission sensor and displays the emission gasses such as CO, SO₂ and NO_x. For flow of air, air speed indicator was used. Three equivalence ratios i.e. 0.8 (lean fuel mixture), 1.0 (stoichiometric fuel mixture) and 1.2 (rich fuel mixture) were used in the combustion test.

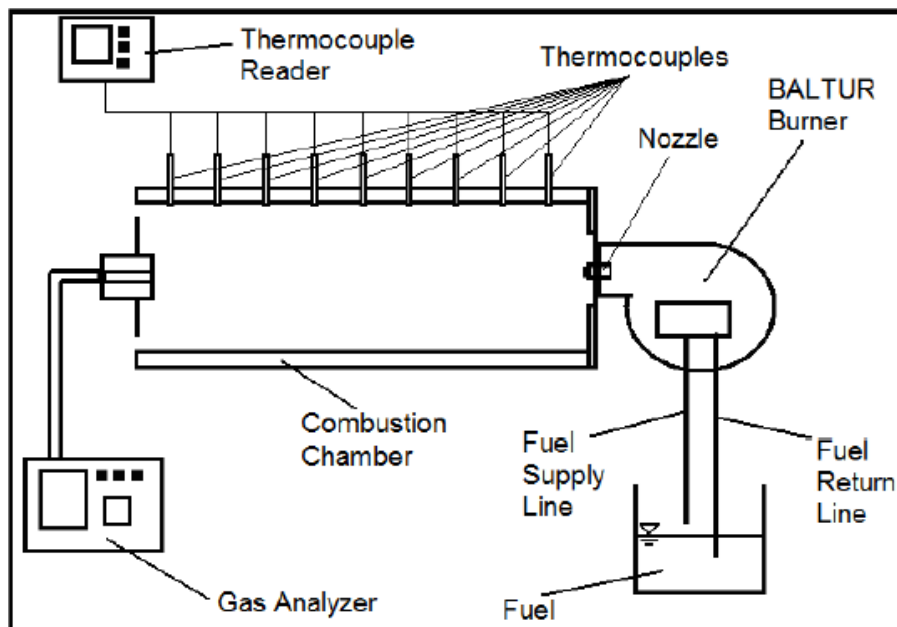


Figure 1. Diagram of experimental setup.



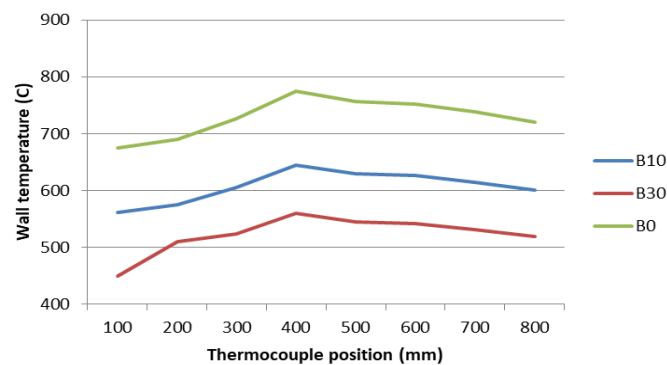
Figure 2. Experimental setup rig.

3. Methodology

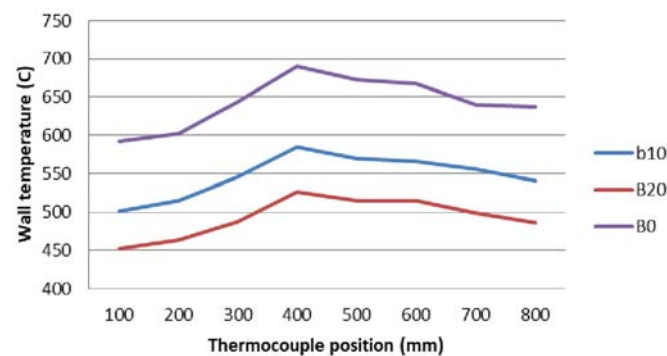
3.1. Wall temperature of the chamber

The wall temperature profile is affected by fuel to air equivalence ratios for diesel and RBOBD blends during combustion. The equivalence ratio is a measure of the amount of fuel to air as compared to the stoichiometric condition. The equivalence ratio below 1.0 means the fuel mixture is lean, while the equivalence ratio of more than one means the fuel

mixture is rich, that is, the fuel is in excess compared to stoichiometric condition [12-13]. In this study the equivalence ratio varied from 0.8 to 1.0, hence the combustion condition changed from a lean fuel mixture to stoichiometric fuel mixture, and then from 1.0 to 1.2, hence the combustion condition changed to rich fuel mixture. In this study, only three equivalence ratio are used 0.8, 1.0 and 1.2 because the profile will significance for the heat released during combustion, if this experiment use equivalence ratio such as 0.4 and 0.6, they are not effective for heat released during the combustion process, if this experiment, large equivalence ratio such as 1.4, more fuel needs to be prepared and will increase the cost of this experiment. From the experimental results, the highest wall temperature was observed at an equivalence ratio of 1.2 [15]. This is due to more fuel being burned at fuel rich mixture conditions, and therefore more heat is released during combustion. The temperature profile pattern for biodiesel blends and diesel is similar to each other as shown in Figure 3 (a), Figure 3 (b) and Figure 3 (c).



(a)



(b)

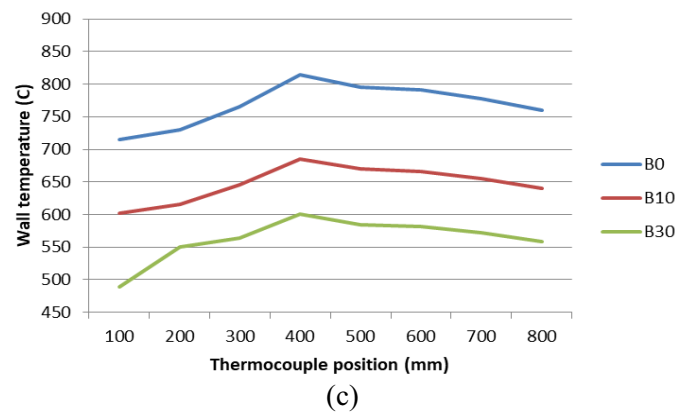


Figure 3. Wall temperature versus thermocouple position at various equivalence ratios, Φ . (a) $\Phi = 0.8$. (b) $\Phi = 1.0$. (c) $\Phi = 1.2$.

3.2. Nitrogen dioxide emissions

The Figure 4 shows that the production of NO_x increases from lean equivalent ratio to stoichiometry equivalent ratio, $\Phi=1.0$. Stoichiometry equivalent ratio ($\Phi=1.0$) is the point of highest production NO_x emission in the combustion process for all fuels. The production of NO_x decreases after this point such as rich equivalent ratio. Also, the highest NO_x producer among the tested fuel is RBOBD B30 followed by B10. The lowest NO_x producer is the conventional diesel (CDF). This means as the percentage of biodiesel increases, the NO_x production becomes higher and higher [15].

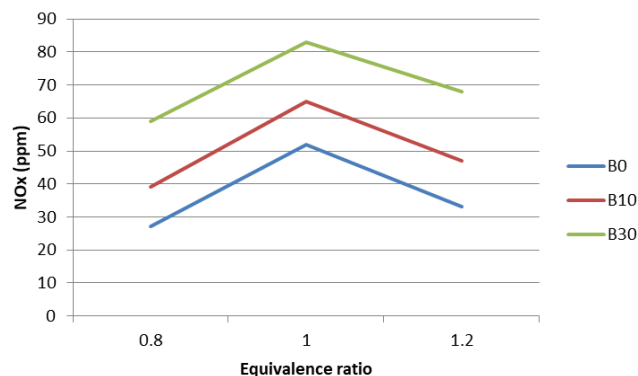


Figure 4. NO_x emissions at different equivalent ratios.

3.3. Carbon monoxide emissions

Figure 5 shows the emission values of RBOBD and that of the fuel at three equivalence ratios such as 0.8, 1.0 and 1.2 which represent lean, stoichiometry and rich mixtures respectively. The graph shows that the production carbon monoxide (CO) decreases from lean equivalent ratio to stoichiometry equivalent ratio and increases again for rich

equivalence ratio of 1.2. Also, the lowest CO producer among the tested fuel is RBOBD B30 followed by B10. The lowest CO producer is the conventional diesel (CDF). This means as the percentage of biodiesel increases, the CO production becomes lower and lower [15].

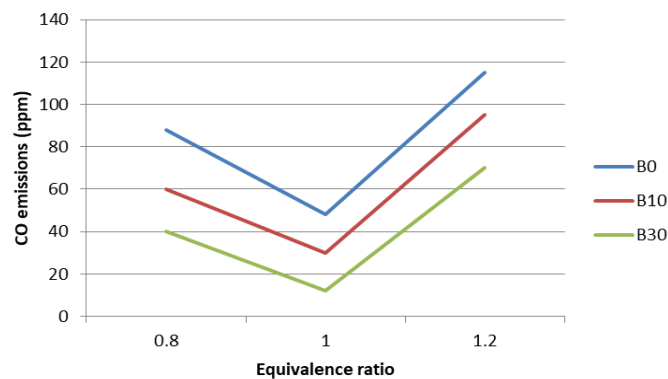


Figure 5. CO emissions at different equivalent ratios.

3.4. Sulphur dioxide emissions

Figure 6 shows the SO₂ emission of RBOBD blends and the CDF is compared at different equivalence ratios. For every tested fuel, SO₂ emission increases in lean fuel mixture till stoichiometric fuel mixture and decreases steadily in a rich fuel mixture. The higher SO₂ emissions are found at stoichiometric equivalent ratio of 1.0. Also, the CDF is seen to be producing more sulphur dioxide emissions followed by B10 and then B30 [15].

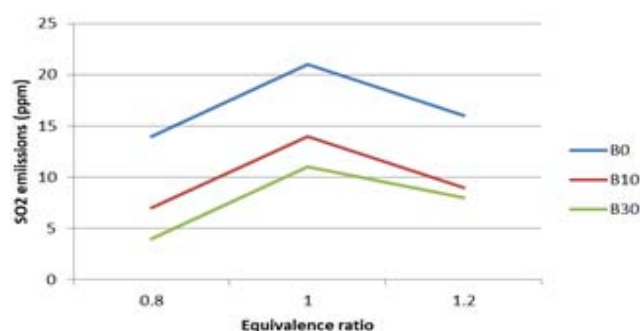


Figure 6. SO₂ emissions at different equivalent ratios.

4. Conclusion

The rice bran oil biodiesel (RBOBD) and conventional diesel fuel (CDF) have been compared in terms of wall temperature profiles and emissions of CO, SO₂ and NO_x at equivalence ratios of 0.8 (lean combustion mixture), 1.0 (stoichiometric mixture) and 1.2 (rich mixture). Experimental results show that the mineral diesel (CDF) produces the highest wall temperature profiles at all equivalence ratios, followed by B10 RBOBD and

then the lowest temperatures are observed for B30 blend. This means that as the percentage of the biodiesel is increased in the pure diesel, the heat produced is reduced. This is because biodiesel in general have lower calorific values. In terms of emissions, the RBO biodiesel is seen to produce less CO and SO₂ emissions compared to CDF and the emissions become less and less as more biodiesel is added to the blend. The higher emissions of SO₂ and the lowest emissions of CO are observed at the stoichiometric equivalence ratio. The emission of NO_x however, is the inverse of the emissions of CO and SO₂, that is, the biodiesel produces more NO_x emissions compared to CDF and the more emissions as the percentage of biodiesel increases in the blend.

Acknowledgment

The authors would like to express their appreciation for the support of the sponsors with Project No. PRGS-4L691, FRGS-4F976, FRGS-5F099 and PRGS-ICC 4J374.

References

- [1] Covert, T., Greenstone, M., & Knittel, C. R. (2016). "Will We Ever Stop Using Fossil Fuels?". *The Journal of Economic Perspectives*. 30(1), pp.117-137.
- [2] Agarwal, A. K. (2007). "Biofuels (Alcohols and Biodiesel) Applications as Fuels for Internal Combustion Engines". *Prog. Energy Combust. Sci.*, 33(3), pp. 233–271.
- [3] Agarwal, A. K., and Das, L. M. (2001). "Biodiesel Development and Characterization for Use as a Fuel in Compression Ignition Engine". *ASME J. Eng. Gas Turbines Power*, 123 (2), pp. 440–447.
- [4] Sinha, S., and Agarwal, A. K. (2005). "Performance Evaluation of a Biodiesel (Rice-Bran Oil Methyl Ester) Fuelled Transport Diesel Engine". *SAE Paper No. 2005-01-1730*.
- [5] Selim, M. Y. E., Radwan, M. S., and Elfeky, S. M. S. (2003). "Combustion of Jojoba Methyl Ester in an Indirect Injection Diesel Engine". *Renewable Energy*, 28, pp. 1401–1420.
- [6] Hasan, M. M., & Rahman, M. M. (2017). "Performance and Emission Characteristics of Biodiesel–Diesel Blend and Environmental and Economic Impacts of Biodiesel Production: A Review". *Renewable and Sustainable Energy Reviews*. 74: pp. 938-948.
- [7] Chhabra, M., Sharma, A., & Dwivedi, G. (2017). "Performance Evaluation of Diesel Engine Using Rice Bran Biodiesel". *Egyptian Journal of Petroleum*. 26(2), pp. 511-518
- [8] Xie, H., Song, L., Xie, Y., Pi, D., Shao, C., & Lin, Q. (2015). "An Experimental Study on the Macroscopic Spray Characteristics of Biodiesel and Diesel in a Constant Volume Chamber". *Energies*. 8(6), pp. 5952-5972.
- [9] Zúñiga-Díaz, J., Reyes-Dorantes, E., Quinto-Hernandez, A., Porcayo-Calderon, J., Gonzalez-Rodriguez, J. G., & Martinez-Gomez, L. (2017). "Oil Extraction from "Morelos Rice" Bran: Kinetics and Raw Oil Stability". *Journal of Chemistry*. 2017, pp. 1-9.

- [10] Senthil Kumar, R. and Manimaran, R. (2014). "Evaluation of a Diesel Engine Using Rice Bran Oil as a Bio-Diesel". *International Journal of Science, Engineering and Technology Research (IJSETR)*. 3, pp. 1779-1789.
- [11] Ahmad, M., Samuel, S., Zafar, M., Khan, M. A., Tariq, M., Ali, S., and Sultana, S. (2011). "Physicochemical Characterization of Eco-friendly Rice Bran Oil Biodiesel". *Energy Sources*. 33, pp. 1386-1397.
- [12] Dhruva, D., & Math, D. M. (2014). "Investigation of Fuel Properties of Crude Rice Bran Oil Methyl Ester and Their Blends with Diesel and Kerosene". *International Journal of Engineering Science Invention*. 3(6).
- [13] Hoekman, S.K., Broch, A., Robbins, C., Ceniceros, E., Natarajan M. (2012). "Review of biodiesel composition, properties, and specifications". *Renew. Sust. Energy Rev.*, (16), pp. 143–169.
- [14] Emmanuel I. Bello & Oluwale O. Oluboba. (2014). "Rice Bran Oil Biodiesel". *European Journal of Engineering and Technology*. Vol. 2 No. 2, 2014. ISSN 2056-5860.
- [15] Agarwal, A. K., Dhar, A. (2014). "Comparative Performance, Emission, and Combustion Characteristics of Rice-Bran Oil and Its Biodiesel in a Transportation Diesel Engine". *Journal of Engineering for Gas Turbines and Power*. 132(6), pp. 1-5.