



A study of effect of sonication on quality of biodiesel

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Abstract

This study evaluates the effect of sonication on biodiesel produced by transesterification of methanol and waste Kings vegetable oil in the presence of a heterogeneous clay catalyst. The fuel properties of biodiesel produced were evaluated according to standard methods. The results revealed that the value of the flash point for the sonicated biodiesel at 10 min (128.40°C) was found to be slightly lower than ASTM D-6751 standard (130.00°C) while sonicated at 30 min (146.10°C) and unsonicated (153.80°C) were higher than the petro-diesel value (54.00°C). The fire point value was high in the biodiesel without sonication and at 30 min but lowest at 10 min. Viscosity values (2.67 mm²/sec, 1.58 mm²/sec and 1.59 mm²/sec) showed that the biodiesel was in accordance with the ASTM standard (1.90-6.00 mm²/sec). The result also revealed that the cetane number for biodiesel without sonication (45.89) and at 30 min (48.60) was in accordance with the ASTM standard while at 10 min (51.00) was higher than the ASTM standard but within the petro-diesel value. The calorific value without sonication (23.20 MJ/kg) and with sonication (28.40 MJ/kg and 31.80 MJ/kg) revealed that the biodiesel produced possesses high power efficiency. The cloud point values (12.00°C, 8.00°C and 9.00°C respectively) were within the acceptable ASTM standard. The density values of the biodiesel without sonication and sonicated (0.94 g/cm³, 0.84 g/cm³ and 0.80 g/cm³ respectively) fell within the acceptable ASTM D-6751 standard. These results show that biodiesel from waste Kings vegetable oil when sonicated could serve as an alternative to fossil fuels.

Keywords: biodiesel, catalyst, transesterification, fuel properties, sonication

Introduction

Biodiesel production and utilization is at its premium in the global market. It is therefore imperative that all activities/processes surrounding biodiesel production be improved to meet up with the geometric demands (Singh and Singh, 2010; Issariyakul and Dalai, 2014) [26, 12].

Due to ecosystem disorder such as global warming, climate changes, acid rain, etc emanating from the use of fossil fuels, Rudolf Diesel initiated research on the production of biodiesel using vegetable oils (Lang *et al.*, 2001; Guara-cho *et al.*, 2009) [15, 10]. Subsequently, researches on the improvement of biodiesel production as the best option to fossil fuels have become systematic and progressive (Adebisi *et al.*, 2019; Aworanti *et al.*, 2019) [1, 3].

The term biofuel generally referred to as renewable transportation fuels from biomass (biological origin) are regarded as one of the most profitable ways of carbon dioxide emissions reduction in the transport sector (Roberts and Patterson, 2014; Alam and Tanveer, 2020) [23, 2]. A variety of fuels can be produced from biomass resources including liquid fuels such as ethanol, methanol, biodiesel, gaseous fuels (hydrogen and methane), etc. World's production of biofuel accounted for 1.5 percent of the global supply of liquid fuels, up by just 0.25 percent from the previous year (Monteiro *et al.*, 2008) [17].

Biodiesel is a biodegradable diesel fuel obtained from vegetable oils, animal fats, recycled auto- mechanic workshop and restaurant greases, etc and has helped several countries in reducing their rely on foreign oil reserve as it is produced domestically and can be used in any diesel engine with little or no modification to the engine or the fuel system (Gincy *et al.*, 2021) [9]. Biodiesel has met the American Society for Testing and Materials (ASTM) D6751 specification and is designated as B100 according to the ASTM (Lam *et al.*, 2010) [14]. The justification of biodiesel as an alternative fuel is remarkably and unarguably seen in the possession of the overall positive life cycle energy balance. It yields as much as 3.2 units of fuel product energy for every unit of fossil energy consumed in its life cycle compared to 0.83 units for petroleum diesel (Sheehan *et al.*, 1998) [25]. However, the advantages of vegetable oil-derived biodiesel as an alternative fuel include fuel performance and lubricity, a higher cetane rating than petro-diesel, a higher flash point that makes it safe to handle, lower toxicity to plants and animals, reduced exhaust emissions, renewability and biodegradability, etc (Ma and Hama, 1999; Encinar *et al.*, 2002; Zhang *et al.*, 2003; Sivaprakasam and Saravanan, 2007) [2, 31, 27].

Biodiesel can be blended and used in many different concentrations. The most common are B5 (up to 5% biodiesel and 95% petro-diesel) and B20 (up to 20% biodiesel and 80% petro-diesel). However, B100 (pure biodiesel) is typically used as a blend stock to produce lower blends and is rarely used as transportation fuel. It can be blended at any level with petroleum diesel to create a biodiesel blend that can be used in compression-ignition (diesel) engines with little or no modification as the superior lubricating properties of biodiesel increases functional engine efficiency.

Biodiesel is obtained through a process called transesterification using vegetable oils with simple alcohol (Devanesan *et al.*, 2009; Ojiego *et al.*, 2014; Gincy *et al.*, 2021) ^[5, 21, 9]. The recovery of biodiesel from the reactor using homogenous liquid catalyst has proved not to be economically viable. Therefore, biodiesel synthesis using heterogeneous solid catalyst could potentially lead to economical production costs due to possibility of reuse of the catalyst (Suppes *et al.*, 2004; Helwani *et al.*, 2009; Obi, 2016) ^[30, 11, 19, 20].

Clays are solid acid catalyst which can function as both Bronsted and Lewis acids in their natural and ion-exchange forms and they are also known as radical catalyst (Nagendrappa, 2011) ^[18]. Clays and clay minerals have been extensively studied for various purposes because of their diversity, chemical composition, structural properties, ionic exchange capacity and related surface charge phenomena. However, the most catalytic properties of clay are due to their acidic character, which is significantly influenced by the clay interlayer structure (Obi and Agha, 2016) ^[19].

Sonication refers to the process of applying electrical energy to agitate particles in a liquid. Ultrasonic frequencies (> 20 KHz) are usually used, so the process is also known as ultrasonication. Sonication can be conducted using either an ultrasonic probe (sonicator) or an ultrasonic bath (Chung, 2001) ^[4]. However, the essence of this application is to completely homogenize the biodiesel produced in order to bring out the best fuel quality properties.

Currently, 95% of global biodiesel productions according to Gincy *et al.* (2021) ^[9] are obtained from edible oils which stand as a competition to human consumption. Consequently, there is serious need to harness waste oils for biodiesel production and subsequently lay out routes, precursors, additives, etc that will yield a cleaner fuel quality and also economic in the management of the process.

Therefore, this study is aimed at the use of ultrasonic energy to evaluate the fuel quality properties of biodiesel produced through transesterification over clay using 'Waste Kings Vegetable Oil'.

Materials and Methods

Sample Collection and Preparation

The raw material used in this work was waste Kings vegetable oil and kaolinite clay (catalyst). The waste Kings oil was obtained from a baked bean shop around Alakahia, Rivers State, and the clay from Isi-Ogo Ogwuta Clay deposit, Afigbo, Ebonyi State.

Transesterification Process of Biodiesel Production

Batch reactor system was adopted by mixing 80 g of methanol and 10 g of kaolinite clay catalyst and refluxed at 80°C for 1 hr as the catalyst activation step. The ratio of methanol to the waste Kings vegetable oil (density = 0.98 g/cm³) was kept constant at 8:15. Then, the 150 ml of the waste Kings oil was added to trans esterify for 8 hrs. Then, 10 g of glycerol was added to the trans esterification product and the separating funnel was shaken vigorously and allowed to stand. The glycerol layer separated from the ester layer within 1 hr. After separation of the two layers, crude methyl esters were washed several times with 50 cm³ of hot distilled water (50°C) in a separating funnel until neutral pH. Finally, the water present was eliminated by heating at 110°C. All sampling solutions were filtered to remove catalyst particle and impurities prior to biodiesel analysis.

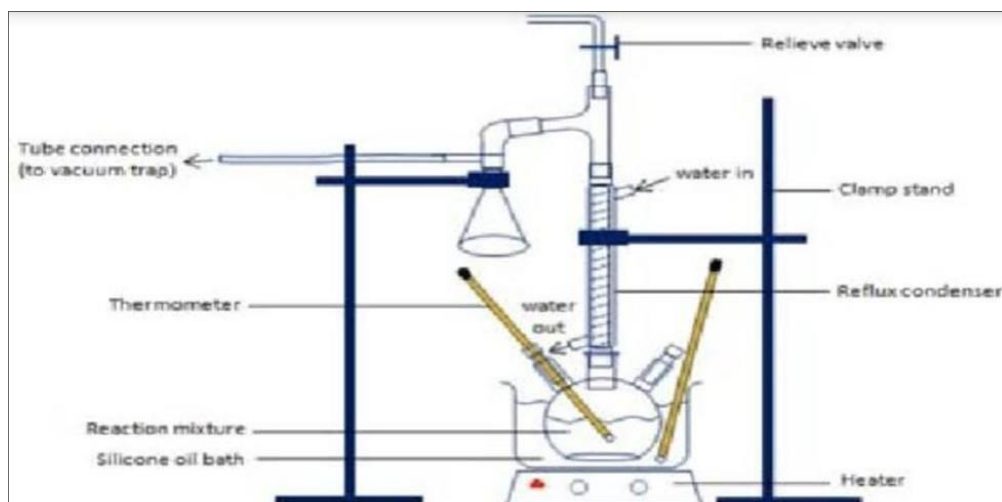


Fig 1: Experimental set up for the transesterification

Sonication Treatment

Prior to the measurement of the fuel quality, the biodiesel produced was subjected to sonication using the ultrasonic cell crusher sonicator (20 KHz) at different times of 10 and 30 min.

Measurement of Fuel Properties

The important physical and chemical properties of biodiesel were determined using standard methods. Methods used are summarized in Table 1.

Table 1: Measuring devices and test methods for measuring fuel properties (Sivaramakrishnan and Ravikumar, 2012)

Property	Measurement apparatus	Standard test methods
Flash and fire point	Pensky – Martens apparatus	ASTM D93
Relative density	Hydrometer	ASTM D941
Calorific value	Bomb calorimeter	ASTM D240
Cetane number	Ignition quality tester	ASTM D613
Viscosity	Redwood viscometer	ASTM D441
Cloud point	Cloud point analyzer	ASTM D2500

Results and Discussion

The result revealed that the values of the flash point for the biodiesel with sonication at 30 min and that without sonication was found to be higher than that of the ASTM D-6751 standard and lower than the petro-diesel value. This indicates the combustive nature of the biodiesel produced. However, the flash point value (128°C) at sonication time of 10 min was within the ASTM D6751 limit but higher than the petro-diesel value (Dias *et al.*, 2008; Ritonga, 2011) [6, 22]. The fire point showed high value for biodiesel without sonication and however, lowest at the sonication time of 10 min (Steven *et al.*, 2015) [29].

The viscosity results showed that the biodiesel was in accordance with the ASTM standard. This reveals that the biodiesel produced can function in the operation of fuel injection equipment (Saddu *et al.*, 2019) [24].

Table 2: Comparison of biodiesel properties obtained (without and with sonication) with the ASTM-D-6751 and petro-diesel standards

Biodiesel properties	Values obtained without sonication	Sonication values obtained at 10 min	Sonication values obtained at 30 min	ASTM (D6751)	Petro-Diesel values
Flash point (°C)	153.80	128.40	146.10	130.00	54.00
Fire point (°C)	181.60	158.50	174.90	-	-
Calorific value (MJ/Kg)	23.20	28.40	31.80	-	-
Relative Density (g/cm ³)	0.94	0.84	0.80	0.89	0.85
Cetane Number	45.89	51.01	48.60	47.00	52.00
Kinematic viscosity @ 40°C (mm ² /sec)	2.67	1.58	1.98	1.90-6.00	3.94
Cloud point (°C)	12.00	8.00	9.00	3-12	-

The result showed that the cetane number for that of the biodiesel without sonication (45.89) and that sonicated for 30 min was in accordance to the ASTM standard while that sonicated at 10 min was higher than the ASTM standard but within the value of petrol-diesel. The high cetane number of biodiesel may be influenced by the physiochemical properties of the feedstock (Jo-Han *et al.*, 2010) [13]. A high cetane number of fuel indicates a good ignition quality. In this work, the calorific values without sonication (23.20 MJ/kg) and with sonication (28.40 MJ/kg and 31.80 MJ/kg) were obtained. According to Elsayed *et al.* (2003) [7], the calorific value was within 37.27 MJ/kg. Therefore, this revealed an indication of high efficiency in the power engine and other related engines.

It was observed that the cloud point values of 12.00°C, 8.00°C and 9.00°C for biodiesel without sonication, at 10 min and 30 min respectively were within the acceptable ASTM standard. The density values of the biodiesel without sonication and with sonication (0.94 g/cm³, 0.84 g/cm³ and 0.80 g/cm³ respectively) fell within the acceptable ASTM standard.

Conclusion

The effect of sonication on the production of biodiesel from waste Kings vegetable oil in the presence of kaolinite clay as catalyst was achieved. The clay catalyst used in this study exhibited a great deal of efficiency on the fuel properties of biodiesel.

The biodiesel fuel properties tested for fell within the acceptable ASTM (D6751) standard except for flash point (without and with sonication at 30 min) and cetane number of sonication at 10 min exhibited values slightly above the ASTM D6751 desirable limit but within the petro-diesel value.

The biodiesel produced showed good ignition quality, high combustibility; power efficiency, etc hence, could serve as a veritable option to fossil fuels.

Conflicts of Interest

The authors declare that no conflict of interest(s) exist.

References

1. Adebisi SA, Amuda OS, Imoh J, Aseez LA. Production of biodiesel from some vegetable oils. *International Journal of Scientific and Engineering Research*,2019;10(12):573-591.
2. Alam SM, Tanveer SM. Conversion of biomass into biofuel: A cutting-edge technology. *Bioreactors*, 2020, 55-74.
3. Aworanti OA, Ajani AO, Agarry SE, Babatunde KA, Akinwumi OD. Evaluation of process parameters for biodiesel production from vegetable and palm waste frying oils using a homogeneous catalyst. *International Journal of Energy Engineering*,2019;9(2):25-35. doi: 10.5923/j.ijee.20190902.01.
4. Chung DDL. Electromagnetic interference shielding effectiveness of carbon materials. *Carbon*,2001;39(2):279-285.
5. Devanesan G, Aravindan R, Viruthagiri T. An overview on the recent advances in the transesterification of vegetable oils for biodiesel production using chemical and biocatalysts. *Journal of Reviews in Environmental Sciences and Biotechnology*,2009;8(4):367-394.
6. Dias M, Hadad AS, Vianna JNS. A Pathway to Energy and Food Security with Biodiesel. *Journal of Sustainable Development, Water and Environment Systems*,2008;4(3):242-261.
7. Elsayed MA, Matthews, R, Mortimer ND. Carbon and energy balances for a range of biofuels options. Report for Project Number B/B6/00784/REP, URN 03/836. Resource Research Unit, Sheffield Hallam University, UK [Online], 2003, 342. Available: <http://www.dti.gov.uk/files/file14925.pdf> [2007 Apr. 05].
8. Encinar JM, Gonzalez JF, Rodriguez JJ, Tajedor A. Biodieselsfuel from vegetable oils: Transesterification of *Cynara cardunculus* L. oils with ethanol. *Energy Fuels*,2002;16:443-50.
9. Gincy MM, Diksha R, Vivek N, Vinod K, Saurabh S, Arivalagam, P *et al.* Recent advances in biodiesel production: Challenges and solutions. *Journal of Science Total Environment*,2021;794:148751. Doi.10.1016/j.scitotenv.2021.148751.
10. Guara-cho VK, Kaminari NMS, Ponte MJJ, Ponte HA. Central composite experimental design applied to removal of nickel from sand. *Journal of Hazardous Material*,2009;172(25):1087-1092.
11. Helwani Z, Othman MR, Aziz N, Kim, J. Solid heterogeneous catalysts for transesterification of triglycerides with methanol: A review. *Applied Catalysis A-General*,2009;363:1-10.
12. Issariyakul T, Dalai AK. Biodiesel from vegetable oils. *Renewable and Sustainable Energy Reviews*,2014;31:446-471.
13. Jo-Han Ng, Hoon K Ng, Suyin G. Advances in biodiesel fuel for application in compression ignition engines. *Clean Technology of Environmental Policy*,2010;12:459-493.
14. Lam MK, Lee KT, Mohamed AR. Homogeneous, heterogeneous and enzymatic catalysis for transesterification of high free fatty acid oil (waste cooking oil) to biodiesel: A review. *Biotechnology Advances*,2010;28:500-518.
15. Lang X, Dalai AK, Bakhshi NN, Reaney MJ, Hertz PB. Preparation and characterization of biodiesels from various bio-cells. *Bioresource Technology*,2001;80:53-62.
16. Ma F, Hanna MA. Biodiesel Production: A review. *Bioresource Technology*,1999;70:1-15.
17. Monteiro M, Pepe AA, Morais L, Ferreira AG. Critical review on analytical methods for biodiesel characterization. *Talanta*,2008;77(2):593-605.
18. Nagendrappa G. Organic synthesis using clay and clay-supported catalysts. *Applied Clay Science*,2011;53(2):106-138.
19. Obi C, Agha II. Base-line characterization of Unwana Ogwuta cave (Iyi Ogo) New site clay in Afikpo, Ebonyi state. *International Journal of Innovative Environmental Studies Research*,2016;4(3):1-6.
20. Obi C. Synergistic Effect of EDTA-modified Bentonite clayn in fatty acid ethyl ester synthesis. *World Applied Science Journal*,2016;34(2):182-188.
21. Ojiego BO, Onyia OC, Abdulraman FW. Production of biodiesel from used vegetable oil. *Global Journal of Biology, Agriculture and Health Sciences*,2014;3(1):274-277.
22. Ritonga M. Biodiesel from Transesterification of *Jatropha curcas* Oil with 7 Free Fatty Acids, 78% with Polystyrene Sulfonate Acid Catalyst (Pss) 1% and 4% within 6 Hours Against Physical Properties (Medan: Universitas Sumatera Utara), 2011.
23. Roberts LG, Patterson TJ. *Encyclopedia of Toxicology*, Third Edition, Biofuels, 2014, 469-475.
24. Saddu S, Kivade SB, Ramena P. The synthesis of biodiesel from used temple oil. *Journal of the Institution of Engineers (India); Series C*,2019;100:701-706.
25. Sheehan J, Dunahay T, Benemann J, Roessler P. A look back at the US department of Energy Aquatic species Program-biodiesel. National Renewable Energy Laboratory, Contract No. DE-AC36-83CH10093, 1998, 328.

26. Singh SP, Singh D. Biodiesel production through the use of different source and characterization of oils and their esters as the substitute of diesel: A review. *Renewable and Sustainable Energy Reviews*,2010:14(1):200-216.
27. Sivaprakasam S, Saravanan CG. Optimization of the transesterification process for biodiesel production and use of biodiesel in a compression ignition engine. *Energy Fuel*,2007:21(5):2998-3003.
28. Sivaramakrishnan K, Ravikumar P. Determination of cetane number of Biodiesel and its influence on physical properties. *Asian Journal of Applied Sciences*,2012:7(2):205-211.
29. Steven AT, Peter RP, David SJJ. *Handbook of Petroleum Processing (2nd Edition)*. Springer, 2015, 79.
30. Suppes GJ, Dasani MA, Doskoil EJ, Mamkidy PY, Goft MY. Transesterification of soybean oil with zeolite and metal catalyst. *Applied catalysis A: General*,2004:257(2):213-223
31. Zhang T, Dube MA, Mclean DD, Kate M. Biodiesel Production from WCO. *Process design and technology assessment. Bioresource Technology*,2003:89(1):1-16.