Comparative studies on the use of palm kernel and coconut oil as biodiesel fuel sources

I.H Ifijen[1], E.U. Ikhuoria[1], S.O Omorogbe[2], O.G Agbonlahor[1]

[1]Department of Chemistry, University of Benin, P.M.B. 1154, Benin City, Nigeria

[2]Product Development Laboratory, Department of Research Operations, Rubber Research Institute of Nigeria, P.M.B. 1049, Benin-City, Nigeria.

ABSTRACT

This research work focuses on the production of biodiesel from palm kernel oil and coconut oil. The biodiesel was prepared by trans-esterification of the oils (unsaturated fatty acid) with an alcohol in the presence of a catalyst to give mono alkyl ester. The biodiesel produced was characterized and analyzed, the properties and the results obtained for biodiesel made from palm kernel oil and coco nut oil include API gravity (21.92 ^{0} C, 25.58^{0}C) , Specific gravity (0.9223, 0.9030), Flash point (64^0 C, 62^0 C) Carbon residue (0.04%, 0.03%), Sediment and Water content (<0.1), sulphur content (0.17%, 0.16%), and iodine value (13.5mg, 12.6mg). Biodiesel made from palm kernel oil was compared with biodiesel made from coconut oil using these properties. The result shows that biodiesel is a good alternative fuel to the conventional fossil diesel since it is more environmentally friendly.

1.0. Introduction

The rising demand for energy amidst depleting petroleum reserves and fluctuating oil prices has stimulated the research into alternative forms of energy such as bio-fuels[1, 2]. The interest in biofuels doesn't lie solely in their ability to provide alternative sources of energy to petroleum and natural gas, but also their environmental safety, affordability, ready availability from vegetable and animal waste, ability to be blended with existing petroleum fuels, and amenability with existing internal combustions engines[2-4]. Particular advantages of biodiesel that makes it of interest to researchers includes its ability to function safely in all conventional diesel engines while offering similar performance and engine lifetime as petroleum diesel [3, 4]. It is also non-toxic, non-flammable, reduces smokes, fumes and other tailpipe emissions. Biodiesel possesses superior properties to petroleum diesel, by having a better flash point, being biodegradable, low in sulphur and aromatic compounds and is generally a cleaner fuel compared to petroleum diesel, since it is oxygenated [3]. A general comparison of bio-diesel to regular D2 fuels revealed that: bio-diesel possesses higher injector coking, 20-50% of the Sulphur content of D2 fuels, higher specific weight, lower heat of combustion, and higher pour points (about 274-298K higher) than petroleum diesel depending on the triglyceride source used [3, 5, 6]. However, the major limitation to the full utilization of bio-diesel as a replacement for petroleum diesel is the high cost of some of the vegetable oils used in its production, as well as the fact that some of these oils are of high nutritional value e.g soybean oil [3, 7, 8]. Suggested means of reducing the net cost associated with bio-diesel production is the purification and commercialization of its bye-product (glycerol), as well as the use of fats and oil wastes form restaurants as triglyceride sources. However, the high amount of free fatty acids present in these waste samples and the fact that free fatty acids can't be esterified by alkaline alcoholysis is a limitation to the implementation of the latter approach [3, 9, 10]. The main methods for producing biodiesel include dilution, micro-emulsion, pyrolysis, and trans-esterification of vegetable oils. These methods mainly serve (among other functions) to reduce the viscosity of the fluid, making it more suitable as a fuel, compared to the raw vegetable oil [3, 8]. Of these methods, trans-esterification has been the most utilized due to its ability to produce fuel (esters) with technical properties similar to that of petroleum diesel[3]. The main factors known to affect the trans-esterification process are temperature and pressure of the reaction, choice of catalyst, duration of reaction, and the triglyceride/alcohol mole ratio. Generally the glyceride/alcohol mole ratio used is 6:1-30:1 [3].

Previous research efforts at producing biodiesel include the use of soybean oil[11], tobacco seed oil[12], safflower oil[13], rapeseed oil[14], *Cynara cardunculus L.* oils[15], among others[7, 16] The quality of the obtained diesel has always been known to be dependent on the synthetic method used, as well as the choice of oils. Generally in trans-esterification, ethanol is the preferred alcohol due to the fact that it can be obtained readily from agricultural products and so provides a means of producing fuels via a totally green approach with less harmful environmental impact compared to methanol [3]. However, methanol generally produces shorter ester chains and is cheaper. In addition, methyl esters have been demonstrated to possess higher power, torque and less injector coke compared to ethyl esters[3].

In this work, bio-diesel was produced by alkaline methanolysis of palm kernel seed oil and coconut oil and the properties of the obtained biodiesel fuel samples were compared.

2.0. Experimentals

2.1.Materials and Methods

Potassium hydroxide, methanol, anhydrous $CaCl_2$ were obtained from Sigma Aldrich Inc (USA). Ultrapure deionized water (18.2MΩ.cm, 25°C), Merck Millipore (Germany) was used for preparing all solutions. The palm kernel oil and coconut oil were bought from stanverd chemical store in Benin City.

2.2. Synthesis of Bio-diesel

The production of bio-diesel from the coconut and palm kernel oils was done using the standard alkali-catalyzed trans-esterification method. In a typical procedure, 3g of potassium hydroxide pellet (KOH) was weighed and dissolved in 60.0ml methanol contained in a 250ml conical flask. This was stirred until the potassium hydroxide pellet dissolved completely to form potassium methoxide (CH_3OK). The potassium methoxide was then poured into 500ml conical flask containing 200ml of palm kernel oil, while stirring continued. The completion of the reaction was indicated by the formation of two liquid layers viz: glycerin and biodiesel. The glycerin phase being denser than the biodiesel was separated using a separating funnel. Thereafter, the biodiesel was washed using warm water to remove residual catalyst or soaps by shaking the mixture till a homogenous solution is formed and allowing the mixture to settle for 5hours. The biodiesel (upper layer) was separated from the aqueous layer (lower layer), and dried using anhydrous calcium chloride ($CaCL_2$).

3.0. Results and Discussion

Characterization of biodiesel made from palm kernel oil and coconut oil.

Table 1,

FUEL PROPERTY	TEST METHOD	RESULT	
		PALM KERNEL OIL	COCONUT OIL
API @ (15^{O}C)	ASTMD12968	21.92	25.58
Specific gravity	ASTMD12968	0.9223	0.9030

Flash point (°C)	ASTMD1310	64	62
Carbon Residue (%)	ASTMD189	0.04	0.03
BS & W (%)	ASTMD323	<0.1	<0.1
Sulphur Content (%)	ASTMD129	0.17	0.16
Iodine value (mg I_2/g oil)	IP-139	13.5	12.6

Density is an important fuel parameter as it affects the general engine performance, efficiency of atomization, cetane number, heating value, and general fuel combustion characteristic[2]. The density of bio-diesel can be determined using the API index or the specific gravity index, with both scales having an inverse relationship i.e the higher the API index, the lower the specific gravity[17].

A general relationship for converting between both scales is given below[17]:

$Specific\ gravity = \frac{141.5}{131.5+API}$………………..(1)

For diesel engines, the density of the fuel is particularly important as the injection system in these engines measures the volume of the fuel, and so changes in density of fuel used will affect the mass of the injected fuel and hence its output power (per unit volume). Generally high fuel densities causes high viscosities and flow resistance resulting in poorer fuel injection [2]. From the obtained results, the biodiesel obtained from coconut oil showed a lower density (higher API value) compared to that from palm kernel oil. Compared to the standard expected for biodiesels both samples had a density slightly above the maximum permissible limit (0.9) [18]. The specific gravity for both biodiesel samples were also higher than that reported for ethyl esters of milkweed oil[19], rapeseed oil[20], soybean oil[20], palm kernel oil[21], and methyl esters of soybean oil[20], rapeseed oil[22], cotton seed oil[20], sunflower oil[20], palm oil[20], jatropha oil[20], rubber seed oil[23] and palm kernel oil[21] .The higher density obtained may be due to the presence of residual water in the biodiesel sample, this is consistent with previous reports in which the presence of higher density liquids generally increased the density of biofuels [1, 2]. Hence, with better post production drying the density of the diesel fuels will be expected to be lower. The flash point of a fuel is another quality control parameter that gives insight into the expected safety of the fuel. The flash point typically represents the lowest possible flammable temperature of the fuel[1, 2]. Though it has no direct impact on the fuel performance and its combustion in the engine system, it is an important safety consideration when transporting the fuel [24]. Technically, it is the minimum temperature, corrected to a 101.3kpa pressure at which the fuel vapour above the sample ignites when an ignition source is applied under specified conditions [2]. The flash point of a fuel varies with the particular fuel under consideration, for biodiesel it should be higher than 120^{o}C [25]. The obtained value for biodiesel from coconut and palm kernel oils were lower than the minimum standard and earlier reports for cottonseed methyl ester (70^{o}C) and palm oil methyl ester (85^{o}C) [20]. The results shows that the biodiesel from palm kernel oil will be slightly more flammable compared to that from coconut oil. The obtained carbon residue of biodiesel from both palm kernel oil and coconut oil was lower than the maximum permissible level of 0.05% [26]. Hence, the expected amount of coke deposit arising from combustion of the biodiesel samples in engines will be within acceptable standards. The carbon residue obtained for both diesel samples, though similar were however slightly higher than that reported for biodiesel from jatropha seed oil (0.20%) [27, 28]. The BS & W (basic sediment and water) relates to the amount of water and contaminants in a biodiesel sample. Residual water in samples usually results from the washing stage involved in the preparation of biodiesel, and so can be reduced by proper drying [29]. However, besides drying, due to the hygroscopic nature of biodiesel, it readily absorbs water also. The residual water is also known to promote biological processes such as formation of sludge and slime and could promote hydrolytic rancidity[29]. Basic sediments usually result from the reaction of oxygen with triglycerides resulting in the formation of hydroperoxides. The hydroperoxides generate radicals which proceed to form polymeric products. When stored in tanks, rust and suspended dirt particles could also contribute to sediments in biodiesel. The maximum permissible limit of BS&W for biodiesel is 0.05(vol%), in the case of the biodiesel from palm kernel oil and coconut oil, the values obtained was <0.1 which is above the permissible limit [29]. The Sulphur content of biodiesel fuels has been reported to directly affect the particulate matter emission [26]. With increasing Sulphur content corresponding to increasing particulate matter emission. The maximum amount of sulphur allowed for biodiesel samples is 0.1 [26]. From the result obtained from the biodiesel samples, the Sulphur content for both samples of biodiesel was higher than the maximum permissible limit. This could be attributed to the amount of Sulphur in the oil samples themselves, as the amount of Sulphur in the original oil samples has been identified as a major factor determining the Sulphur content of biodiesel samples [30]. The iodine value of a diesel sample relates to the amount of unsaturated bonds in the fuel. From the obtained result, the degree of unsaturation in the biodiesel obtained from palm kernel oil was slightly higher than that obtained from coconut oil. The maximum permissible limit for iodine value in biodiesel is 120 mg I_2/g oil [29, 31]. The iodine values obtained for both oil samples were below this limit, and suggest that the biodiesel is quite stable to oxidation processes. The iodine value was also lower than that reported for soybean oil methyl ester (133.2) and rapeseed oil methyl ester (97.4)[20], but similar to earlier reports for biodiesel obtained by methanol alcoholysis of palm kernel oil (14-22) and coconut oil (8-10) [32].

The close values of the fuel parameters in both the biodiesel obtained palm kernel and coconut oil can be attributed to the similar carboxylic acid profiles of both oil samples [32].

4.0. Conclusion

This study shows that palm kernel oil and coconut oil are viable sources of biodiesel. The obtained biodiesel from both palm kernel oil and coconut oil showed similar fuel properties on comparison and were generally acceptable when compared to standards. However, care will be needed in transporting the products due to the low flash points observed in both samples.

References

1. Onaifo, J.O., Ikhuoria, E.U., Omorogbe, S.O., Agbonlahor, O.G., Ifijen, I.H., *Coconut pith an alternative source of producing renewable material (bioethanol).* Journal of Applied Chemical Science International, 2016. **6**(2): p. 80-84.
2. Shahir, S.A., Masjuki, H.H., Kalam, M.A., Imran, A., Rizwanul Fattah, I.M., Sanjid, A., *Feasibility of diesel-biodiesel-ethanol/bioethanol blend as existing CI engine fuel: An assessment of properties, material compatibilty, safety and combustion.* Renewable and sustainable energy reviews., 2014. **32**: p. 379-395.
3. Demirbas, A., *Biodiesel fuels from vegetable oils via catalytic and non-catalytic supercritical alcohol transesterifications and other methods: a survey.* Energy conversion and management, 2003. **44**: p. 2093-2109.
4. Chand, N., *Plant oils—fuel of the future.* J Sci Ind Res 2002. **61**: p. 7-16.

5. Saka, S., Kusdiana D., *Biodiesel fuel from rapeseed oil as prepared in supercritical methanol.* Fuel, 2001. **80**: p. 225-231.
6. Komers, K., Stloukal, R., Machek, J., Skopal, F., *Biodiesel from rapeseed oil, methanol and KOH 3. Analysis of composition of actual reaction mixture.* Eur J Lipid Sci Technol, 2001. **103**: p. 363-371.
7. Goering, E., Schwab, W., Daugherty, J., Pryde, H., Heakin, J., *Fuel properties of eleven vegetable oils. 1982;25:1472–83.* Trans ASAE 1982. **25**: p. 1472-1483.
8. Karaosmonoglu, F., *Vegetable oil fuels: a review.* Energy Sources, 1999. **21**: p. 221-231.
9. Ma, F., Hanna, M.A., *Biodiesel production: a review.* Biores Technol, 1999. **70**: p. 1-15.
10. Canakci, M., Van Gerpen, J., *Biodiesel production from oils and fats with high free fatty acids. .* Trans ASAE, 2001. **44**: p. 1429-1436.
11. Pryor, R.W., Hanna, M.A., Schinstock, J.L., Bashford, L.L., *Soybean oil fuel in a small Diesel engine. .* Trans ASAE, 1982. **26**: p. 333-338.
12. Giannelos, P.N., Zannikos, F., Stournas, S., Lois, E., Anastopoulos, G., *Tobacco seed oil as an alternative Diesel fuel: physical and chemical properties.* Ind Crop Prod 2002. **16**: p. 1-9.
13. Isigıgur, A., Karaosmonoglu, F., Aksoy, H.A., *Methyl ester from safflower seed oil of Turkish origin as a biofuel for Diesel engines.* Appl Biochem Biotechnol, 1994. **45/46**: p. 103–12.
14. Mittelbach, M., Gangl, S., *Long storage stability of biodiesel made from rapeseed and used frying oil.* JAOCS 2001. **78**: p. 573-577.
15. Encinar, J.M., Gonzalez, J.F., Rodriguez, J.J., Tejedor, A., *Biodiesel fuels from vegetable oils: transesterification of Cynara cardunculus L. oils with ethanol. .* Energy Fuels, 2002. **16**: p. 443-450.
16. Lang, X., Dalai, A.K., Bakhshi, N.N., Reaney, M.J., Hertz, P.B., *Preparation and characterization of bio-diesels from various bio-oils.* Biores Technol, 2001. **80**: p. 53-63.
17. Association, R.F., *Fuel ethanol industry guidelines, specifications and procedures*. 2011: www.ethanolrfa.org.
18. Rutz, D., and Janssen, R., *Overview and Recommendations on Biofuel Standards for Transport in the EU*, in *Project: BiofuelMarketplace*. 2006.
19. Holser, R.A. and R. Harry-O'Kuru, *Transesterified Milkweed (Asclepias) seed oil as a biodiesel fuel.* Fuel, 2006. **85**: p. 2106-2110.
20. Bamgboye, A.I. and O.O. Oniya, *Fuel properties of loofah (Luffa cylindrica L.) biofuel blended with diesel A. .* African Journal of Environmental Science and Technology., 2012. **6**(9): p. 346-352.
21. Alamu, O.J., M.A. Waheed, and S.O. Jekayinfa, *Biodiesel production from Nigerian palm kernel oil: Effect of KOH concentration on yield.* Energy Sustain. Dev., 2007. **11**(3): p. 77-82.
22. Labeckas, G. and S. Slavinskas, *The effect of Rapeseed oil methyl ester on direct injection diesel engine performance and exaust emissions.* Energy Conversion and Management., 2006. **47**(1954-1967).
23. Ramadhas, A.S., C. Muraleedharan, and S. Jayaraj, *Performance and emission evaluation of a diesel engine fuelled with methyl esters of rubber seed oil.* Renewable Energy, 2005. **30**: p. 1789–1800.
24. Rao GLNR AS, N., N., Sakthivel, P., *Relationships among the physical properties of biodiesel and engine fuel system design requirement.* Int. J. Energy Environ., 2010. **1**: p. 919-926.
25. Barabás, I., Todoruţ ,I-A., *Utilization of biodiesel-diesel-ethanol blends in CI engine. Biodiesel-quality, emissions and by-products.*, G. Montero, and Stoytcheva, M., Editor. 2011, InTech. p. 215-234.
26. HARSONO, S.S., *Biodiesel production from palm oil technology.* Research Journal of Agricultural Science., 2011. **43**(4): p. 80-85.
27. Meher, L.C., D.V. Sagar, and S.N. Naik, *Technical aspects of biodiesel production by transesterification- A review.* Renew. Sust. Energy Rev., 2006. **10**: p. 248-268.

28. Ranganathan, S.V., S.L. Narasimhan, and K. Muthukumar, *An overview of enzymatic production of biodiesel.* Bio-resource. Technology., 2008. **99**: p. 3975-3981.
29. Ferrari, R.A., Pighinelli, A.L.M.T., and Park, K.J., *Biodiesel Production and Quality, Biofuel's Engineering Process Technology.*, D.M.A.D.S. Bernardes, Editor. 2011, InTech, Available from: http://www.intechopen.com/books/biofuel-s-engineering-processtechnology/biodiesel-production-and-quality.
30. He, B.B., Van Gerpen, J. H., Thompson, J. C., *Sulfur content in selected oils and fats and their corresponding methyl esters.* Applied Engineering in Agriculture, 2009. **25**(2): p. 223-226.
31. Knothe, G., *Analyzing Biodiesel: Standards and Other Methods.* JAOCS, 2006. **83**(10).
32. Opara, C.C.a.O., E. L., *Potentials of Using Nigerian Vegetable Oils For Biodiesel Production.* Petroleum Technology Development Journal: An International Journal 2009. **1**: p. 1-12.