Asian Journal of Chemical Sciences

8(4): 11-17, 2020; Article no.AJOCS.61871
ISSN: 2456-7795

Physicochemical Evaluation of the Oil Extracted from *Anacardium occidentale* Almonds for Energy Use

Yete Pélagie[1,2*], Togbe F. C. Alexis[1], Yovo Franck[1], Suanon Fidèle[1], Kouwanou Sagbo Cosme[2], Wotto D. Valentin[1,2] and Sohounhloue Dominique[2]

[1]Department of Chemistry, Faculty of Science and Technology, University of Abomey-Calavi, Abomey-Calavi, Benin.
[2]Department of Chemical Engineering-Processes, Polytechnic School of Abomey-Calavi, University of Abomey-Calavi, Abomey-Calavi, Benin.

Authors' contributions

This work was carried out in collaboration among all authors. Author YP designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors TFCA and YF managed the analyses of the study. Authors SF and KSC managed the literature searches. Authors WDV and SD gave some advices. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJOCS/2020/v8i419049
Editor(s):
(1) Pradip K. Bhowmik, University of Nevada, USA.
Reviewers:
(1) Akleshwar Mathur, JIET Group of Institutions, India.
(2) Thitiphan Chimsook, Maejo University, Thailand.
Complete Peer review History: http://www.sdiarticle4.com/review-history/61871

Received 01 August 2020
Accepted 06 October 2020
Published 22 October 2020

Original Research Article

ABSTRACT

The present study aimed at exploring the potential of producing biofuels from unconventional vegetable oils extracted from *Anacardium occidentale* kernels. Accordingly, oils were extracted from *Anacardium occidentale* kernels and subjected to physical and chemical characterization namely: density; lower calorific value (PCI); quality indexes; fatty acid profile, viscosity using French and ISO standards.

Results revealed that *Anacardium occidentale* almonds have a lipidic potential of 52.54%, the transesterification reaction yield was 78.28%. As for the quality indices of the vegetable oil: acidity (>1%); saponification index (205.29 mg KOH/g-oil); peroxide value (8.08 meq O2/kg-oil) and iodine value (108.84 mg iodine/g-oil) were considerably reduced for biodiesel. The vegetable oil was

---

**Corresponding author: E-mail: pelagie.yete@yahoo.fr;*

unsaturated type with the predominance of oleic acid (43.86%). The fuel characteristics of the oil obtained were: acidity (2.89%), density at 40°C (0.796 g/cm^3) cetane number (41.47). The raw extracted oil is not usable as fuel for engine due to its very high viscosity ranging 30.69 mm^2/s. As a consequence, a prior chemical treatment is necessary to reduce the viscosity.

Our results provided an insight on the energetic potential of the investigated oil, with respect to its use as a source for biodiesel in replacement of the current conventional diesel fuel.

Keywords: Anacardium occidentale; physico-chemical and thermodynamic parameters; fuel capacity.

1. INTRODUCTION

Development and growth in industrial and transport sectors has led to a high use of petrochemicals [1]. As result, petroleum products are getting increasingly expensive and their combustion produces greenhouse gases that are largely responsible of climate change. It is reported that fossil fuels such as oil cover 80% of global energy consumption [2]. Nowadays, several countries across the globe are redirecting research towards alternative energies, including biofuels [3].

Several studies have shown the importance of biomass valorization, which has recently become very popular, particularly for rich carbohydrate raw materials (cereals, beets and sugar cane), lignocellulosic (wood, straw and fodder) or oleaginous (vegetable oils) [4,5]. However, this way of producing so-called first-generation biofuels is part of the creation of a new agricultural sector and contrasts with food production leading to a shortage in the market and a rise of food raw material prices [6].

It is therefore necessary to seek to produce biofuels from non-food or less consumed and abundant sources, without affecting the food balance or food security. Accordingly, in the republic of Benin, research in this field is directed on our local species producing less consumed oils.

In Benin, the biofuel sector was launched in 2007 with the signing of a memorandum of understanding for technical cooperation between Benin and Brazil. Since then, agricultural products such as cassava, sugar cane and cashew apple have been identified for bioethanol production. Similarly, palm oil and castor oil traditionally produced in large quantities in Benin, as well as *J. Curcas*, were selected to be transformed into biodiesel for the production of electricity and transport.

The present study aims to determine the physico-chemical and thermodynamic parameters of oils extracted from *A. occidentale* kernels for the synthesis of a biofuel which physicochemical and thermodynamic properties are similar to conventional diesel.

2. MATERIALS AND METHODS

2.1 Sample Collection

A. occidentale seeds were harvested at Teval in northern Benin in Copargo city. Nuts were dried for 7 days in the laboratory at room temperature (25°C) and were mechanically crushed using a hammer. The manually separated almonds were dried in air at 25°C for 10 days before the determination of the water content and volatile matter according to NF T 60- 201 standard.

2.2 Oil Extraction

Oil extraction from *A. occidentale* were preceded using Soxhlet apparatus and hexane as a solvent under 69 ± 1°C under atmospheric pressure, for 6h.

2.3 Physicochemical Properties

Water content, density and viscosity were determined according to the standardized methods (DIN EN ISO 12937, NF T 60-214, NF ISO 3104). The acid, peroxide and saponification index of the extracted oils were determined following the French standards T 60-204; T 60-220 and T 60-206. The iodine value was evaluated by the Winkler method. The calorific value was determined according to [7] and the cetane number was calculated from the Klopfenstein equation [8].

2.4 Mineral Elements

Mineral elements contents of *A. occidental* oils were dosed according to the dry procedure by Inductive Coupled Plasma (ICP) on a Varian-Vista device equipped with the Coupled Charge Device (CCD) detector.

2.5 Fatty Acids Contents

To determine the fatty acid composition, 1 µL of a hexane solution of methyl esters was injected into an Agilent 6890 HP GC series (Agilent, USA) equipped with an Innowax (Agilent, USA) type column, 30 m long, 0.32 mm internal diameter having a film thickness of 0.25 µm. The injector was in split mode, ratio 1/80 at 250°C as temperature. The carrier gas was helium with a flow rate of 1.5 $mL.min^{-1}$.

3. RESULTS AND DISCUSSION

3.1 Physical and Chemical Characteristics of the Extracted Oil

The extraction yield of the oil from Benin's *A. occidentale* toasted almonds was evaluated in term of lipid content (51.80% ± 0.38). The yield is higher than that extracted from raw samples from Nigeria [9,10]. Almond's toasting has significantly decreased water content (0.08 ± 0.01) and significantly improved the extraction yield. The high lipid content may foster lipid extraction by press. This performance allowed a more thorough characterization of the obtained oil. Thus, the chemical characteristics of the oil are presented in Table 1.

3.1.1 Peroxide value

The vegetable oils from *A. occidentale* present a peroxide value of 8.08 meq O_2/kg-oil. This value is lower than that of Nigeria oils (19.75 - 20.84 meq O_2/kg oil) as reported by [11], and higher than that reported by [10]. The peroxide values determined for the vegetable oils is below the limit of 10 meq O_2/kg-oil, which is the maximum level allowed for most conventional oils [12]. Accordingly, the oils did not undergo major degradation by oxidation [13].

3.1.2 Iodine value

The determination of the iodine value is used to determine the degree of unsaturation of fatty acids in the oil. The oil iodine value (108.84 g I_2/100 g-oil) of *A. occidentale* almonds of Benin has a value greater than those of Nigeria oils studied by [11] but is smaller than the value reported by [10]. This value is higher than that of the palm oil (50.0 to 55.0). It is in the same order of magnitude as those of corn oil (103-135 g I_2/100 g-oil) and cotton (100-123 g I_2/100 g-oil) [14]. The high value of the iodine value is related to the unsaturated nature of the extracted oil.

However, the iodine values of *A. occidentale* in this studies comply with the limit (120 g I_2/100 g-oil) set by EN 14214 standards [15] and corroborate the composition of these oils, which are rich in unsaturated fatty acids (studied below). This could justify the fluidity of *A. occdentale* oils.

3.1.3 Saponification value

In this study, the saponification value obtained was 205.29 mg KOH/g-oil. The sample of saponification is higher than that found by [10] but is smaller than those reported by [11] for *A. occidentale*'s oils from Nigeria. However, it is in the same order of magnitude as those of edible oils of palm (190-209 mg KOH/g of oil), cotton (189-198 mg KOH/g of oil), peanut (187 - 196 mg KOH/g oil) and soy (189-195 mg KOH/g oil) required by the Codex Alimentarius. They are similarly lower than those of vegetable oil of *J. curcas* conventionally used for biodiesel (196 and 208 mg KOH/g-oil) as reported by [16]. This could reflect a low short chain fatty acids content of our samples [12].

3.1.4 Fatty acids profile of the oils

The obtained results regarding fatty acid composition of *A. occidentale* kernels are presented in Table 1. It appears that the fatty acid composition is marked by the predominance of oleic acid (C18:1) following by palmitoleic acid (C16:1) and linoleic acid (C18:2). The particularly high proportions of oleic acid indicate that the oil is stable to oxidation and can be stored for a long time [17]. However, [18] reported that high unsaturation of the oil could reduce the cetane number of its biodiesel. The cetane number is related to the ignition delay. The shorter the carbon chain is the higher the cetane number.

3.2 Fuel Properties of the Vegetables Oils

Fuel characteristics such as: water content, acid number, density, viscosity, cetane number, phospholipids, Na+K, Ca+Mg and calorific value of the oils were determined. The results are presented in Table 2. From the results, it appears that:

3.2.1 Acid value

The acid value of a vegetable oil is a function of its free fatty acids and characterizes the state of

Table 1. Physicochemical parameters

Physicochemical property	*Anacardium occidentale*
Peroxide value (meqO_2/kg-oil)	8.08±0.12
Iodine value (g I_2/100 g-oil)	108.84±0.74
Saponification value (mg KOH/g-oil)	205.29±0.32
Palmitic acid (C16:0)	12.65±0.02
Stearic acid (C18:0)	6.35±0.09
Oleic acid (C18:1)	43.86±0.21
Linoleic acid (C18:2)	12.50±0.18

Table 2. Fuel properties of vegetable oils

Fuel characteristics	Values	Normes
Water content (%)	0.08±0.001	<0.075
Acid value (mg KOH/g)	1.140±0.090	<2.0
Density (g/cm^3, 40°C)	0.796±0.001	0.910-0.930
Viscosity (mm^{2}s^{-1}, 40°C)	30.69±0.000	<38
Cetane number	41.47±1.005	
Phospholipids (ppm)	33.00±0.021	<12
Na + K (ppm)	112.20±0.000	<5
Ca + Mg (ppm)	120.00±0.020	<5
Calorific value (KJ/kg)	38161±0.400	> 35000

alteration of the oil by hydrolysis [19]. The acid values (1.140 mg KOH/g) for our oils (< 2 mg KOH/g-oil) are below the limit of 3 mg KOH/g-oil for rapeseed and slightly exceed 0.5 mg KOH/g-oil fixed for the reference biodiesel [15]. These acid numbers, however, remain lower than those of *J. curcas* oils from eight localities in Benin as studied by [16].

This result allows us to direct our work towards basic catalysis in order to transesterify the studied oil, without any pre-treatment of the oil or pre-treatment or catalysis, to reduce this acidity. Based on previous work [20], the efficiency of the transesterification reaction would decrease if the acidity level exceeds 2%, which would favor the saponification reaction (reverse reaction) in the reactive medium and create difficulties in phase separation when recovering the synthesized biodiesel (product of the transesterification reaction).

3.2.2 Viscosity

The viscosity increases with the degree of saturation of the oil. Generally, this property represents the biggest difference between a vegetable oil and conventional fuel. Indeed, vegetable oils are generally ten times more viscous than diesel at 40°C and thirty times more viscous at 0°C. High viscosity does not promote spraying or atomization when injecting fuel. The pressure required for injection will have to increase and combustion efficiency will be poor. This leads to unburned parts that cause the cylinder and piston to become dirty and the fuel supply system to become clogged [21]. Its maximum accepted value for a fuel application is 38 mm^2/s. In our case, the value found (≈30.69 mm^2/s at 40°C) is within the limits of ASTM D6751 and EN 14214 specifications.

3.2.3 Cetane number

The cetane number represents the ability of a fuel to self-ignite under standard pressure conditions. It is directly related to the ignition delay of the fuel in the combustion chamber after injection. The higher the cetane number, the easier the fuel ignites (easier cold start). The cetane number of vegetable oils is generally lower than the cetane number of a Conventional diesel, this is due to the chemical structure of these oils, as well as their degree of saturation. This index is between 29 and 43 [22], while the cetane number for diesel has an average value of 45. In our case, the cetane number of *A. occidentale* oil is estimated to be 41.47. This index is in the same order of magnitude as that of most common vegetable oils.

3.2.4 Calorific value

The calorific value determined here is the lower calorific value. Its minimum value for a fuel application is set at 35000 KJ/Kg. The calorific value for the oil studied is 38161 KJ/kg. This value is higher than the minimum predicted by the German pre-standard (35000 kJ/kg) for a biodiesel [15]. In most cases, vegetable oils have a lower Lower Calorific Value (PCI) than gasoil in the range of 5 to 18%.

3.2.5 Phospholipid, (Na + K) and (Ca + Mg) content

Phospholipids come directly from the breakdown of cell walls within the plant biomass. Their concentration depends on the techniques used. The phospholipid content (33.00 ppm), the Na + K content (112.20 ppm) and the Ca + Mg content (120.00 ppm) are extremely high for both studied oils. Their values pass the data foreseen by the norms. When oils are used in an engine, phospholipids polymerize under the effect of heat and are responsible for the formation of deposits that clog injectors and accumulate on combustion chamber walls, valves and cylindrical surfaces. The oils should be refined through several processes to decrease these values. In literature several authors such as [23] proposed chelating agents such as EDTA (Ethylene-Diamine-Tetra-Acetic acid) and citric acid to reduce metallic cations in matrices.

3.3 Influence of Temperature on the Viscosity of Vegetable Oils

The variation in viscosity, an important physical characteristic of *A. occidentale* oil, as a function of temperature is shown in Fig. 1.

It is easy to conclude that it would be interesting to determine the viscosity at 40°C in order to be able to carry out a comparative study with this physical characteristic of the biodiesel produced from this oil. Thus, for this temperature, we obtain a viscosity value equal to 30.69 mm^2/s.

These results show that *A. occidentale* oil cannot be used directly as a fuel in a diesel engine, it is therefore imperative to reduce its viscosity to a value similar to that characterizing conventional diesel (1.5 - 4.5 mm^2/s).

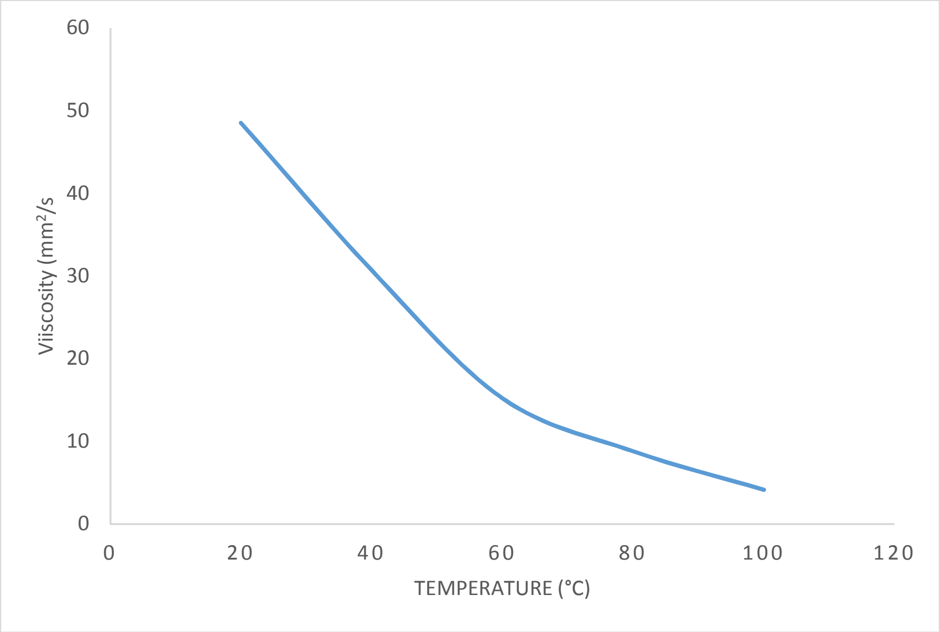

Fig. 1. Influence of temperature on the viscosity of vegetable oils of *A. occidentale*

4. CONCLUSION

The physicochemical and thermodynamic properties of *A. occidentale* oil obtained by standard methods and compared with those of other vegetable oils used as a source of biodiesel production; show a good concordance with the literature. Thus, the oil extracted from *A. occidentale* kernels presents fuel characteristics that meet the standards recommended for the production of biofuels. *A. occidentale* oil is characterized by a high viscosity and a modification outside of transesterification (preheating) is necessary before use. Future studies will focus on producing these biofuels by several methods for energy use.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Baird NC, Cann M, JO-Seleau J, Perraud R. Chimie de l'environnement. [S.I.]: Louvain-la-Neuve: De Boeck supérieur, DL, cop. BU Santé QH 10 BAI; 2016. ISBN 978-2-8041-9217-4
2. Ballerini D, Lemarchand J, Appert O, Pappalardo M, Roy C. Le plein de biocarburants? enjeux et réalités, [S. I.]: Paris: Éditions Technip. IFP publications. BU Sciences et Philosophie 662.88 BAL PLE; 2007. ISBN 978-2-7108-0882-4
3. Guinde L, Jacquet F, Millet G. Impacts du développement des biocarburants sur la production française de grandes cultures. Revue d'études sur l'agriculture et l'environnement. 2008;89:55–82.
4. Demirbas FM, Balat M, Balat H. Biowastes-to-biofuels. Energy Conversion and Management. 2011;52(4):1815-1828.
5. Yete P, Togbe A, Yovo F, Wotto V, Sohounhloue D. Nutritional potential of co-products of two species of benin cucurbits. American Journal of Physical Chemistry. 2019;8(4):75-81.
6. Benoist A. Eléments d'adaptation de la méthodologie d'analyse de cycle de vie aux carburants végétaux: Cas de la première generation. Paris, France. 2009; 226.
7. Batel W, Graef M, Meyer GJ, Moller R, Schoedder F. Pflonzenole fur die Kraf tstof fund. Energie versorgung. Grundlagen der Landtechnik. 1980;30(2):40-51.
8. Klopfenstein WE. Estimation of cetane index for esters of fatty acids. Journal of the American Oil Chemists' Society. 1982; 59(12):531-533.
9. Aremu MO, Olonisakin A, Bako DA, Madu PC. Composition studies and physicochemical characteristics of cashew nut (Anacardium occidentale) flour. Pakistan Journal of Nutrition. 2006;5(4): 328-333.
10. Aletor O, Agdebe JO, Adeyeye SA, Aletor VA. Chemical and physiochemical characterization of the flour and oils from whole and rejected cashew nuts cultivated in southwest Nigeria. Pakistan Journal of Nutrition. 2007;6(1):89-93.
11. Olugunde OM, Omosebi MO, Ariyo O, Olunlade BA, Abolaji RA. Preliminary nutritional evaluation of cashew nuts from different locations in Nigeria. Continental Journal Food Science and Technology. 2011;5(2):32–36.
12. Ferhat R, Laroui S, Abdeddaim M. Oil and fatty acids of the almonds of the *crataegus azarolus*. Lebanese Science Journal. 2014;15(2):73-79.
13. Abdelaziz B, Djamila S. Olive growing: Characterization of six varieties of olives in the South East of Algeria. European Scientific Journal. 2016;12(33):1857-7881.
14. Wotto DV, Yété P, Nonviho G, Sessou P, Sohounhloué D. Fatty acids tocopherols and sterols profiles of *cucumeropsis edulis* unconventional oil seeds. World Journal of pharmacy and pharmaceutical sciences. 2015;4(11):167-17.
15. CIRAD, Technical guide for the use of vegetable fuel in stationary engines. Harmattan Burkina, P. 2014;111.
16. Kpoviessi DSS, Accrombessi GC, Kossouoh C, Soumanou MM, Moudachirou M. Physical-chemical properties and composition of the non-conventional oil to *Jatropha curcas* from different regions of Benin. Academy of Sciences, C.R Chemistry. 2004; 7:1007-1012.
17. Lamaisri C, Punsuvon V, Chanprame S, Arunyanark A, Srinives P, Liangsakul P. Relationship between fatty acid composition and biodiesel quality in nine commercial palm oil. Songklanakarin Journal of Science and Technology. 2015;37(4):389-395.
18. Gopinath A, Puhan S, Nagarajan G. Effect of unsaturated fatty acid esters of biodiesel

fuels on combustion, performance and emission characteristics of a diesel engine. International Journal of Energy and Environment. 2010;1(3):411-430.

19. Bettahar Z, Cheknane B, Boutemak K. Study of transesterification of a mixture of waste oil for biodiesel production. Renew able and Sustainable Energy Reviews. 2016;19(4):605-615.
20. Park YM, Lee JY, Chung SH. Esterification of used vegetable oils using the heterogeneous WO_3/ZrO_2 catalyst for production of biodiesel. Bioresource Technology. 2010;101:n° 1.
21. Denis J, Briant J, Hipeaux JC. Physicochimie des lubrifiants: Analyses et essais, Analyses des huiles en services ou usages. Edition Technip. 1997;460.
22. Blin J. Guide technique pour l'utilisation d'huile végétale carburant dans les moteurs Diesel stationnaires. Editions Sud Sciences et Technologies, Ouagadougou, Burkina Faso; 2014.
23. Cuvelier ME, Maillard MN. Stability of edible oils during storage. Ocl Oils Fat Crop Li. 2012;19(2):125-132.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/61871