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Characterization of some nonconventional oils from Burkina Faso

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Abstract : In order to find alternative sources of raw materials for biodiesel production, oils from *Azadirachta indica*, *Balanites aegyptiaca*, *Detarium microcarpum*, *Jatropha curcas*, *Ximenia americana* seed kernels and *Lannea microcarpa* dried fruits were evaluated in a comparative study for their fatty acid profiles and physicochemical characteristics. Oil contents obtained for these six plant materials collected in Burkina Faso varied from 8.4 (*D. microcarpa*) to 51.7% (*J. curcas*). Oleic acid was predominant in majority of these oils with a highest value for *X. americana* (82.50%). Oil from *L. microcarpa* had the highest content in palmitic acid (34.06%). High values of polyunsaturated fatty acids were observed in *X. americana*, *D. microcarpum* and *B. aegyptiaca* oils 8.34% of ω-3, 46.53 and 45.32% of ω-6, respectively. The kinematic viscosity at 50 °C of *X. americana* oil (256.85 cSt) was 10 times higher than those of other oils. *D. microcarpum* and *A. indica* oils had relatively high values of cloud and pour points, +13 and +9 °C for the first and +9 and +6 °C for the second. Considering the fatty acid profiles and physicochemical properties of *D. microcarpum*, *L. microcarpa* and *X. americana oils*, *L. microcarpa oil* seems to be the most appropriate for biodiesel production, while *X. americana* and *D. microcarpum* oils are recommended for nutritional use.

Keywords: non conventional oils, physicochemical characteristics, fatty acid composition, biodiesel, nutrition.

Caractérisation de quelques huiles non conventionnelles du Burkina Faso

Résumé: Dans le but de trouver des sources alternatives de matières premières pour la production du biodiesel, le profile chimique et les caractéristiques physicochimiques d'huiles issues des amandes d'*Azadirachta indica*, de *Balanites aegyptiaca*, de *Detarium microcarpum*, de *Jatropha curcas*, de *Ximenia americana* et de fruits séchés de *Lannea microcarpa* ont été évaluées dans une étude comparative. Les teneurs en huile, obtenues pour ces six matières végétales collectées au Burkina Faso ont varié de 8,4 (*D. microcarpum*) à 51,7% (*J. curcas*). L'acide oléique était le composé prédominant dans la majorité de ces huiles avec une plus grande teneur dans celle de *X. americana* (82,50%). L'huile de *L. microcarpa* a eu la teneur la plus élevée en acide palmitique (34,06%). Les fortes teneurs en acides gras polyinsaturés ont été observées pour les huiles de *X. americana*, *D. microcarpum* et *B. aegyptiaca*, les valeurs étaient respectivement 8,34% de ω-3, 46,53 et 45,32% de ω-6. La viscosité cinématique à 50 °C de l'huile de *X. americana* (256,85 cSt) était 10 fois plus élevée que celle des autres huiles. Les valeurs des points de trouble et d'écoulement des huiles de *D. microcarpum* et *A. indica* étaient relativement élevées, +13 et +9 °C pour la première et +9 et +6 °C pour la seconde. Au regard des profils en acides gras et des propriétés physicochimiques des huiles de *D. microcarpum*, *L. microcarpa* et *X. americana*, l'huile de *L. microcarpa* semble être la mieux appropriée pour la production du biodiesel, tandis que les huiles de *X. americana* et *D. microcarpum* sont recommandées pour une utilisation nutritionnelle.

Mots clés : huiles non conventionnelles, caractéristiques physicochimiques, composition en acides gras, biodiesel, nutrition.

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1. Introduction

Sahelian region is known as producer of many vegetable oils (cottonseed, peanut, sesame, shea oils). However, local production of these oils isn't enough for alimentation, medicinal and industrial purposes. Some wild plants (*Adansonia digitata*, *Sclerocarya birrea*, *Moringa oleifera*) are sources of edible oils [1-3]. In the domain of energy, to face the growing demand in biodiesel without competing with food uses, non-edible oils *(Azadirachta indica*, *Balanites aegyptiaca* and *Jatropha curcas*) are exploited as alternate feedstock for biodiesel production [4, 5]. In order to find other potential sources, non-conventional oils are also prospected [5, 7, 9]. *Detarium microcarpum* Guill. and Sperr., *Lannea microcarpa* Engl. and *Ximenia americana* Linn. concerned by non-conventional oils, are less studied in Africa. On the other hand, to produce biodiesel from local non-edible oils, it is necessary to specify their fatty acid composition as an important data in setting up the transesterification process (molar ratio oil: alcohol).

In this paper, we report the analysis of these non conventional oils obtained by hexane extraction compared to well known oils used in biodiesel production *(Azadirachta indica*, *Balanites aegyptiaca* and *Jatropha curcas* oils). The analysis focused on oil contents, physicochemical parameters and the triglycerides fatty acids profiles in order to confirm the potential use of each oil in biodiesel production and to contribute to the improvement of the transesterification process of these oils.

2. Experimental section

2.1. Plant material

Plant materials were collected from different climatic regions of Burkina Faso, dried under sunlight for a week and stored at room temperature: Sahelian region for *A. indica* (Ouahigouya, June 2009), *J. curcas* (Toma, December 2008), *L. microcarpa* (Ouagadougou, July 2009) and Soudano-Sahelian region for *B. aegyptiaca* (Nouna, November 2009), *D. microcarpum* (Pô, May 2009) and *X. americana* (Yallé, June 2009). The flowers, leaves, fruits and seeds of *D. microcarpum*, *L. microcarpa* and *X. americana* were identified at the Herbarium of the University of Ouagadougou, Burkina Faso. Other species, *A. indica*, *B. aegyptiaca* and *J. curcas*, are well- known and easily identifiable.

2.2. Oil extraction

Oils were extracted from the powder of different plant materials (kernels or fruits), using *n*-hexane (HPLC grade) in a Soxhlet extractor at 60 °C following ISO 659:1998(F) modified method (micro grinding and two steps extraction for eight hours).

2.3. Analytical methods

2.3.1. Physicochemical analysis

Physical and chemical parameters for each oil were carried out according to standard methods: acid value (ISO 660:2009(F)), relative density (ASTM D- 4052-96), kinematic viscosity (ASTM D- 445), pour (ASTM D97-93) and cloud (ASTM D2500-91) points.

2.3.2. Fatty acid analysis

The fatty acid composition was determined as methyl esters after transesterification. All chemicals and solvents used are the analytical quality.

2.3.2.1. Sample preparation.

150 µL of the methyl esters were mixed with 1 mL of 0.75 mg/mL internal standard solution (undecanoic acid C11:0 dissolved in *n*-hexane) and diluted to 20 mL with *n*-hexane. For GC analysis, each sample was performed by dissolving of 400 µL of methyl esters sample into 400 µL of *n*-hexane.

2.3.2.2. GC analysis.

The fatty acid profiles of oils are determined by using a ThermoFinnigan type Trace (20090 Rodano (MI), Italy) gas chromatograph equipped with a flame-ionization detector. GC conditions were as follows: 1 µL of sample is inserted on column (100 m, 0.25 mm i.d. and 0.2 µm film thickness). The operational conditions are:

injector temperature, 225 °C; column flow, 200 kPa; detector temperature, 255 °C; H_2 flow, 35 mL/min; air flow, 350 mL/min. Oven temperature was initially 80 and raised to 175 °C at a rate of 25 °C/min (25 min hold), raised to 205 °C at a rate of 10 °C/min (4 min hold) and finally raised to 225 °C at a rate of 10 °C/min (20 min hold). The instrument was controlled with ChromQuest (ThermoFinnigan) software.

3. Results and discussion

The data obtained for oil contents and various physicochemical analysis of the six extracted oils are summarized in **table I**. The fatty acid composition for each oil is given in **table II.**

Oil content

As shown in table I, the oil contents in plant materials are high except for *D. microcarpum* seed kernels which oil content was 8.4%. It is in good accordance with the values reported in the literature [6, 8]. The hexane-extracted oil content was high for the five other plants and the best oil content (51.7%) was noted for *J. curcas* seed kernels.Basing on the oil extraction yield, *J. curcas*, *A. indica* and *B. aegyptiaca* can be considered as the best non-edible feedstock for biodiesel production

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Table I: Physicochemical parameters of the oils.

Oils	Oil content (%)	Acid value (mg KOH g^{-1})	Relative density (g/cm^3)		Kinematic viscosity (cSt)		Cloud Point (°C)	Pour Point (°C)
			15 °C	25 °C	37.8 °C	50.0 °C		
A. indica	45.1	2.20	0.914	0.907	40.67	26.83	+9	+6
B. aegyptiaca	46.3	0.70	0.915	0.908	30.92	21.27	+1	0
D. microcarpum	08.4	1.82	0.907	0.900	30.62	20.53	+13	+9
J. curcas	51.7	7.20	0.916	0.909	37.03	24.69	-1	-3
L. microcarpa	27.9	16.00	0.911	0.904	40.03	25.73	-	+6
X. americana	38.9	1.90	0.917	0.910	-	256.85	+10	-9

Table II: Fatty acid composition of oils.

Fatty acid	*A. i.*	*B. a.*	*D. m.*	*J. c.*	*L. m.*	*X. a.**
Caproic (C6:0)	-	-	0.03	-	-	-
Capric (C10:0)	0.05	0.05	0.08	0.05	0.06	0.12
Lauric (C12:0)	0.02	0.02	0.03	0.01	0.03	0.04
Tridecylic (C13:0)	0.02	0.02	0.03	0.03	0.03	0.05
Myristic (C14:0)	0.05	0.06	0.06	0.06	0.31	0.04
Pentadecylic (C15:0)	0.02	-	0.02	0.01	0.03	-
Palmitic ISO (C16:0)	0.02	-	0.02	-	-	-
Palmitic (C16:0)	**17.60**	**13.79**	**10.99**	**15.56**	**34.06**	**3.42**
Palmitoleic (C16:1 *trans*-Δ^9)	-	-	-	-	-	0.04
Palmitoleic (C16:1 *cis*-Δ^9)	0.11	0.14	0.06	0.92	0.15	0.22
Margaric (C17:0)	0.13	0.11	0.09	0.08	0.16	-
Stearic (C18:0)	**17.46**	**11.07**	2.51	7.34	7.12	2.43
Elaidic (C18:1 *trans*-Δ^9)	0.21	-	-	-	0.63	-
Oleic (C18:1 *cis*-Δ^9)	**46.84**	**28.25**	**35.36**	**42.53**	**42.96**	**82.50**
cis-Vaccenic (C18:1*cis*-Δ^{11})	0.52	0.72	0.68	1.23	1.19	0.51
Linoleic (C18:2 *cis, cis*-Δ^9, Δ^{12})	**14.90**	**45.32**	**46.53**	**31.84**	**11.84**	1.73
Arachidic (C20:0)	1.55	0.33	1.21	0.19	1.02	0.56
Linolenic (C18:3 *cis, cis, cis*-Δ^9, Δ^{12}, Δ^{15})	0.44	0.06	-	0.16	0.31	0.82
Eicosatrienoic (C20:3 *cis, cis, cis*-Δ^{11}, Δ^{14}, Δ^{17})	-	-	1.23	-	-	1.70
Arachidonic (C20:4 *cis, cis, cis, cis*-Δ^5, Δ^8, Δ^{11}, Δ^{14})	-	-	0.03	-	-	-
Docosapentaenoic (C22:5 *cis, cis, cis, cis, cis*-Δ^7, Δ^{10}, Δ^{13}, Δ^{16}, Δ^{19})	0.05	0.06	0.99	-	0.13	5.82
Clupanodonic (C22:6 *cis, cis, cis, cis, cis, cis*-Δ^4, Δ^7, Δ^{10}, Δ^{13}, Δ^{16}, Δ^{19})	-	-	0.04	-	-	-
Total saturated	36.92	25.45	15.07	23.32	42.80	4.45
Total unsaturated	63.08	74.55	84.93	76.68	57.20	95.55

* *A. i.*: *Azadirachta indica; B. a.*: *Balanites aegyptiaca; D. m.*: *Detarium microcarpum; J. c.*: *Jatropha curcas; L. m.*: *Lannea microcarpa; X. a.*: *Ximenia americana.*

Fatty acid profile

It has been noticed that the fatty acid compositions of *J. curcas*, *B. aegyptiaca* and *A. indica* oils from Burkina Faso are comparable to those of other geographic regions [5, 7].

The predominant fatty acids of *J. curcas* oil were oleic (42.53%) and linoleic (31.84%) acids. The fatty acid composition of *B. aegyptiaca* oil has the same profile as jatropha oil, but the predominant fatty acid in the *B. aegyptiaca* oil is linoleic acid (45.32%).

T *X. americana* oil contains high percentage of long chain fatty acids with high molecular weight of it (table II). The total unsaturation of *X. americana* oil was 95.55% with predominance of oleic acid (82.50%). Moreover, this oil is characterized by significant notable contents of ω-3 like docosapentaenoic (5.82%), eicosatrienoic (1.70%) and α-linolenic (0.82%) acid and ω-6 as linoleic (1.73%) acid. The high level of polyunsaturated fatty acids in this oil promotes the polymerization and oxidation processes and provides it an unstable character. Due to this unfavorable factor, *X. americana oil* is not suitable to produce biodiesel.

The percentage of major fatty acids (palmitic (10.99 %), oleic (35.36 %) and linoleic (46.53 %) of *D. microcarpum* oil is comparable to that of *B. aegyptiaca* oil. However, *D. microcarpum oil* is richer in ω-3 like docosapentaenoic (0.99%) and eicosatrienoic (1.23%) acids. The presence of essential fatty acids procures the high nutritional value to both *D. microcarpum* and *X. americana* oils. Unlike *X. americana* and *D. microcarpum* oils, *L. microcarpa edible fruits oil* contains high proportion of saturated acids with a predominance of palmitic acid (34.06%). However, it was lower than that reported in literature [1]. Attention should be paid to the presence of *trans*-isomer of oleic acid (elaidic acid, 0.63 %) in *L. microcarpa oil* which is undesirable for edible purposes. The fatty acid profile of *L. microcarpa* oil is similar to that of palm oil which is the main biodiesel feedstock throughout the world [4, 5].

L. microcarpa oils had high acid value (16.0 mg KOH g^{-1}) comparatively to other oils (0.7 to 7.0). The acid value is associated to the deteriorating rate of the oil. This parameter is very important in edible oils refining process (quality/price) and in the manufacture of biodiesel (quality/yield). The hydrolysis of triglycerides caused by lipolytic activity of the fruit lipase and micro-organisms could be one reason of high level of free fatty acids in this oil [10, 11]. The high free fatty acids content of the oil requires appropriate storage conditions (short term storage, low temperature, waterproof container).

Viscosity and density

The high percentage of polyunsaturated linoleic acid makes *B. aegyptiaca* oil less viscous (30.92 cSt) than those of *J. curcas* (37.03 cSt) and *A. indica* (40.67 cSt). The high content in saturated acids as palmitic (17.60%) and stearic (17.46%) for *A. indica* oil is in good accordance with those indicated by Karmakar (2011) [4]. This high concentration of saturated fatty acids is a good criteria for high stability and cetane number which increases with the fatty acids chain length [12].

The relative density at 25 °C of *X. americana* oil was slightly high (0.910 g/cm3). Note that D. *microcarpum* and *L. microcarpa oils* are the least dense than other studied oils, 0.900 and 0.904 g/cm^3, respectively. In fact, these oils contain more short chain saturated fatty acids (capric, myristic, etc). *D. microcarpum oil* is also the least viscous (30.62 cSt) compared to other oils. If non-conventional oils from *D. microcarpum*, *L. microcarpa* and *X. americana* are intended to be used as biofuel, low density and viscosity values are favorable for atomization in diesel engine or blending with the conventional fuel (0.855 g/cm^3) [13].

Cloud and pour points

Relatively high cloud and pour points were noticed for *A. indica* oil, +9 and +6 °C, respectively, which is an indication that this oil can be used in hot climatic conditions.

. Thecloud and pour points for *D. microcarpum* are higher (+13 and +9 °C respectively), however, its pour point is identical to that of soybean oil according to Stern et *al.* (1983) [14]. The dark brown color of *L. microcarpa* oil has prevented establishing its cloud point but the pour point was +6 °C. The solidification of these oils or their esters at low temperature is a major difficulty for their use as biodiesel in cold weather condition. *X. americana* oil is distinguished from others by a very high viscosity (256.85 cSt at 50 °C). However, it was significantly lower than that reported by Eromosele (450.80 cSt at 50 °C) [15].

4. Conclusion

Non conventional oils from different species widespread in Burkina Faso possess interesting characteristics and can be exploited to produce biodiesel or edible oils. A complete fatty acid composition of each studied oil provides new information on their minor components such as *trans*, polyunsaturated and saturated short chain fatty acids. It also helped to set the best condition for transesterification and optimize the process for local production of biodiesel. Regarding to oil content, fatty acid profiles and physicochemical properties of non conventional oils, *L. microcarpa* oil appears to be acceptable for biofuel use as *J. curcas*, *A. indica* and B. *aegyptiaca* oils. The high percentage in polyunsaturated fatty acids and the high viscosity of *X. americana* oil are the adverse factors for using this oil as fuel. *X. americana* and *D. microcarpum* oils rich in ω-3 and ω-6 are an alternative and available resource of essential fatty acids for human nutrition.

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