African Journal of Biotechnology Vol. 11(22), pp. 6138-6142, 15 March, 2012
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB11.2674
ISSN 1684–5315 © 2012 Academic Journals

Full Length Research Paper

Physicochemical characterization and fatty acid content of ‘venadillo’ (*Swietenia humilis* Zucc.) seed oil

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Accepted 17 January, 2012

Physicochemical properties of *Swietenia humilis* Zucc seed oils were determined along with its fatty acid composition, by using gas-liquid chromatography. The oil content found in the germ portion of the seeds was 45.38%. From physicochemical oil evaluations, an oil density of 0.9099 mg·ml^{-1} at 28°C; a refraction index of 1.4740 at 20°C; a saponification index of 159.55 mg KOH·g^{-1}; a peroxide index of 0.739 meq O_2·kg^{-1}, and 0.367% free fatty acid content were shown. From chromatographic oil evaluations, eight fatty acids were identified showing palmitic (C16:0), stearic (C18:0), oleic (C18:1 cis-9), linoleic (C18:2 cis-9,12), and linolenic (C18:3 cis-9,12,15) as the most predominant. The percentage of saturated, monounsatured and polyunsatured fatty acids were at 18.45, 29.27 and 47.50%, respectively. These results show that ‘venadillo’ oil has a high content of essential fatty acids, mainly linoleic and linolenic. Therefore, this oil shows promissory uses as nutritional component to reduce the cholesterol and triglyceride levels in blood, mostly from patients with higher cardiovascular disease risks.

Key words: Oil, α-linolenic acid, linoleic acid, oilseeds, *Swietenia humilis*.

INTRODUCTION

The tree *Swietenia humilis* Zucc. belongs to the Family Meliaceae, subfamily Swietenioideae and it is native of Mexico. The genus Swietenia has three species, *Swietenia*: *mahagoni* Jacq., *macrophylla* King and *humilis* Zucc.; they are located in the tropics and subtropics of the American continent (Pennington, 1981). The tree is commonly known as ‘venadillo’ in Sinaloa (Northwest of Mexico), and in other regions of Mexico as ‘zopilote’, ‘caobilla o cóbano’ (Martinez, 1979). This species is located in both dry and humid tropical forests on the pacific coast of Sinaloa, Colima, Michoacan, Guerrero and Chiapas, in Mexico (Standley, 1920). In Culiacan, Sinaloa *S. humilis* trees are used for reforestation of avenues and public parks due to its resistance to pests and droughts. *S. humilis* reaches up to 20 m tall with a dome-shape canopy, a trunk measuring 30 to 50 cm in girth, and white to yellow small flowers grouped in clusters. The fruit are woody ovoid capsules, 15 to 20 cm long, 10 to12 cm wide, with 45-60 winged seeds with kernels up to 2 cm long (Pennington, 1981). *S. humilis* is a source of wood used to make furniture and, in some regions in Mexico, is used as medicinal tree to control diabetes (Niembro-Rocas, 1990). Its seeds are used to eliminate gastrointestinal parasites such as helminthes and amoebas (Segura-Correa et al., 1993). The parasiticide effect may be related to the presence of complex structure-limonoid compounds known as humilinoloids A-D, which have shown insecticidal activity both on *Ostrinia nubilalis* (Jimenez et al., 1997) and *Spodoptera frugiperda* larvae (Fowles et al., 2010). In addition, the fungicide activity of alcoholic extracts of *S. humilis* in the *in vitro* control of *Rhizopus stolonifer* has been demonstrated (Angulo-Escalante et al., 2009).

Based on the physicochemical characteristics of a vegetal oil, it could be exploited in the food industry (Stuchlik and Zak, 2002), for pest control (Nikpay, 2007) or in the cosmetics industry (Almeida et al., 2006). For

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example, the vegetal oil from *Prunus dulcis* (Mill.) is broadly used in the cosmetics industry to make soaps, gels and creams due to its moisturizing, lubricant and smoothing action on the skin, properties conferred mainly by its type and rates of fatty acids in its structure: palmitic (5.46 to 15.78%), palmitoleic (0.36 to 2.52%), stearic (0.80 to 3.83%), oleic (50.41 to 81.20%) and linoleic (6.21 to 37.13%) (Askin et al., 2007). There are other commercially important products from coconut oil and cocoa butter with similar uses, but with different composition (Stuchlik and Zak, 2002).

The objective was to characterize the physicochemical quality of oil from *S. humilis* seeds from Sinaloa. The yield of oil-rich seeds in *S. humilis* in addition to the few studies showing toxicity effects and the search for new sources of oil to be used in the industry was supported in this study.

MATERIALS AND METHODS

Sampling and handling of 'venadillo' seeds

Fruit sampling was conducted on 'venadillo' trees located at the Universidad Autonoma de Sinaloa campus in Culiacan, Mexico. Six trees were randomly selected and 10 kg of fruits were collected in each tree. Fruits collected showed visible split opening indicating its physiological maturity. Seeds were separated manually, sun-dried for 4 h and then air-dried in shadow for 15 days. Finally, samples collected from each tree were divided into three subsamples and stored at 50°C for further studies. Seed area was determined by measuring seed length and width.

Oil quantification

Quantification of seed oil was determined according to AOAC 920.39 (AOAC, 1998) method by using a gold fish oil extractor (Labconco, USA). Briefly, a sample of 2 g of seed kernels was ground and then placed in an extraction thimble, to be introduced in an extraction beaker filled with 30 ml of anhydrous petroleum ether (reagent grade). The sample was heated with a constant fluid for 4 h and the solvent was separated by distillation using the Goldfish oil extractor. Then, the beaker was placed in a forced air oven (GCA Corporation, USA) at 100°C, until a total evaporation of the solvent. Oil percentage was determined by weight difference among the extraction vases.

Physicochemical characterization

Chemical and physical analyses of seed oil were determined by AOAC methods (AOAC, 1998). Density of the oil sample was determined by method 920.50, refraction index by 921.08, saponification index 920.160, peroxide index 965.33, and free fatty acids 940.28.

Fatty acid composition

Fatty acid composition in 'venadillo' seed oil was determined by gas-liquid chromatography. Lipid extraction was carried out according to the method of Folch et al. (1957). A tissue homogenizer (Ultra-Turrax, Germany) was used to mix a sample of 2 g of ground seed, 10 ml of methanol and 20 ml of chloroform. The sample was filtered and placed in a separation funnel. The process was repeated three times. Filtered sample was mixed with KCl 0.88% to form two phases. The lower phase was separated and purified with a mixture of methanol:distilled water (5:5). Finally, the chloroform in the sample was evaporated in a water bath with a stream of nitrogen to obtain the lipid phase.

Fatty acid methylation was conducted by the AOAC method 969.33 (1998). The oil sample was mixed with 10 ml NaOH 0.5 N, 12 ml BF3 14% and 4 ml n-heptane in a volumetric flask with reflux for 5 to 10 min. The volumetric flask was removed from heating and its content was mixed with a saturated solution of NaCl to form two phases. The upper layer containing n-heptane was transferred to an assay tube with anhydrous Na_2SO_4 and was filtered by using a packed fiber glass. The filtered sample was stored in a 2 mL-amber vial. Furthermore, the methylated fatty acid analysis was determined using a CP-3800 series gas chromatography (Varian, Palo Alto, CA), equipped with flame ionization detector and a silica capillary column 30 m × 0.32 mm × 0.25 µM (Omegawax 320, Supelco, Bellefonte, PA, USA), (AOAC, 1998). The injector and detector temperature were programmed at 260°C, and the injection volume was 1 µL. Helium (3 ml·min^{-1}) was used as the carrier gas. Fatty acid identification and quantification was determined using a mixture of 37 fatty acid methyl ester standards C4-C24 (Supelco, Bellefonte, PA). Results were shown as fatty acid percentages.

Statistical analysis

A descriptive statistical analysis conducted by Minitab 14.0 was used to analyze the results of oil content, density, refractive index, peroxide value, saponification value and free fatty acids.

RESULTS AND DISCUSSION

Oil yield and physicochemical properties

Morphological characteristics and oil content extracted with anhydrous petroleum ether from seeds of *S. humilis* are described in Table 1. The average content of oil was 45.38%, with variations between 36.90 and 54.35%. These results are similar to sunflower seeds, where there is a direct relationship between size and oil content in the seeds (Pineda and Avila, 1993). The physical and chemical characteristics of 'venadillo' oil are shown in Table 2. The mean value of 'venadillo' seed oil density at 28°C was 0.9099 mg.ml^{-1}. This value is similar to the density of avocado oil (0.9098 mg.ml^{-1}) (Jimenez et al., 1997). It has been suggested that the lipid density is directly related to the unsaturated grade of the fatty acids in the oil (Ohlson, 1983). Hence, 'venadillo' oil density indicates a high content of unsaturated fatty acids.

The mean of refraction index at 20°C was 1.4740 for 'venadillo' oil extracted with petroleum ether. This index is related with the unsaturated grade in the fatty acid molecules; for example, oil from *Moringa oleifera* var. Periyalukam has a high unsaturated grade and has a refraction index of 1.460 (Lalas and Tsaknis, 2002; Farag et al., 2007). The saponification index was 159.55 mg KOH·g^{-1} (Table 2). This value is below to the saponification index from olive oil (188.00 mg KOH.g^{-1})

Table 1. Morphological characteristics and oil content in 'venadillo' (*Swietenia humilis* Zucc.*)* seeds from trees in Culiacan, Mexico.

Characteristic	Tree					
	1	2	3	4	5	6
Length (mm)	21.71 ± 0.76	23.20 ± 0.38	18.57 ± 0.34	18.16 ± 0.40	18.58 ± 0.36	18.10 ± 1.24
Width (mm)	11.60 ± 0.39	11.00 ± 0.20	10.23 ± 0.40	10.27 ± 0.40	9.95 ± 0.06	9.30 ± 0.26
Area (mm^2)	251.91 ± 1.77	254.87 ± 2.72	194.31 ± 0.74	183.89 ± 0.24	182.42 ± .30	172.60 ± 7.10
Oil content (%)	47.7 ± 7.8	54.4 ± 4.6	47.6 ± 6.3	43.7 ± 1.9	42.1 ± 3.2	36.9 ± 8.3

Values are given as mean ± standard deviation (n = 3).

Table 2. Physical and chemical characteristics of 'venadillo' (*Swietenia humilis* Zucc.*)* seed oil from trees in Culiacan, Mexico.

Characteristic	Tree					
	1	2	3	4	5	6
Density (mg mL^{-1})	0.9130 ± 0.007	0.9071 ± 0.006	0.8986 ± 0.012	0.9088 ± 0.004	0.9218 ± 0.002	0.9099 ± 0.009
Refraction index (nD20°C)	1.4767 ± 0.00	1.4664 ± 0.00	1.4758 ± 0.00	1.4756 ± 0.00	1.4752 ± 0.00	1.4740 ± 0.00
Saponification index (mg KOH g^{-1})	179.99 ± 1.04	155.46 ± 10.92	166.83 ± 13.47	151.28 ± 2.74	156.06 ± 5.48	147.69 ± 4.15
Peroxide index (meq O_2kg^{-1})	0.731 ± 0.02	0.750 ± 0.00	0.742 ± 0.01	0.740 ± 0.01	0.730 ± 0.01	0.740 ± 0.01
Free fatty acids (% oleic acid)	0.27 ± 0.20	0.39 ± 0.01	0.39 ± 0.00	0.39 ± 0.00	0.39 ± 0.00	0.37 ± 0.05

Values are given as mean ± standard deviation (n=3).

and avocado oil (189 mg KOH·g^{-1}). This could be due to the fact that compounds from a saponifiable fraction are mainly triglycerides (glycerol and free fatty acids) and that the oleic, palmitic, linoleic and stearic are the predominant fatty acids (Jimenez, 2001; Ollivier et al., 2003; Loyola et al*.,* 2008). Consequently, olive oil has a higher concentration of oleic acid in a range from 55 to 83% and palmitic acid from 7.5 to 20% than 'venadillo' oil that contains oleic acid in a range of 25.85 to 31.90% and palmitic acid from 4.99 to 7.28% (Table 3).

The peroxide value from 'venadillo' seed oil was 0.739 meq O_2·kg^{-1} (Table 2). This value shows that although 'venadillo' oil is susceptible to oxidative reactions due to its high unsaturated grade, the oxidative grade is minimal since the oil was properly stored and exposure to oxygen was avoided. The average of free fatty acids in the 'venadillo' seed oil was 0.367% (Table 2). This average suggests that 'venadillo' oil has a low hydrolytic deterioration. The presence of free fatty acids is favored by the presence of short-chain fatty acids. In the case of 'venadillo' oil, percentage of short- and intermediate-chain fatty acid is minimal in comparison with *Jatropha curcas* oil (Adebowale and Adedire, 2006). A gas chromatogram from an analysis of fatty acid methyl esters of 'venadillo' seed oil is illustrated in Figure 1. Eight peaks were observed and the identification and quantification of fatty acids was conducted by comparing of the retention time generated under the same conditions from the standard of a mixture of 37 fatty acid methyl esters C4-C24 with the 'venadillo' sample.

Composition and rates of fatty acids from 'venadillo' oil are shown in Tables 3 and 4. The level of saturated fatty acids in 'venadillo' oil was 18.45%, with the highest content of stearic acid (C18:0), and a mean value of 11.39%. Consumption of this fatty acid in food does not increase the fatty levels in plasma blood due to its fusion point above the temperature of the human body. This means that it is solid at 37°C and is probably eliminated in the feces before the absorption by the intestinal walls. Also it is believed that this acid is denaturalized quickly to oleic acid and its own effect could be lost during digestion (Harwood and Yaqoob, 2002; Dubois et al., 2007). In the food industry, seeds that have high content of stearic acid such as cocoa (36.4%) are used in the elaboration of chocolate, while shea nuts (41%), and mango seed oil (40.3%) are used in the cosmetics industry (Dubois et al., 2007). The monounsaturated fatty acid, oleic acid (C18:1cis-9) with a mean of 29.27% was found in the 'venadillo' oil. This fatty acid has a beneficial action in the blood vessels by reducing the risk of cardiovascular diseases. Oils rich in this type of fatty acid are considered essential for good human health; for example, the olive oil that contains 55 to 83% of oleic acid (Harwood and Yaqoob, 2002; Dubois et al., 2007).

The total content of polyunsaturated fatty acids was 47.50%, with linoleic acid (C18:2 cis-9,12; omega 6) with a value of 29.82% and linolenic acid (C18:3cis-9,12,15; omega 3) also known as α-linolenic with a value of 16.65% the most predominant. These two fatty acids are considered essentials in the human diet because they are precursors of several fatty acids involved in different biochemical reactions in the organism. For example the α-linolenic acid forms the docosahexaenoic acid (DHA; C22:6; omega 3) and the eicosapentaenoic acid (EPA C20:5; omega 3), which reduce triglyceride level in a range of 10 to 30% in patients suffering from diabetic

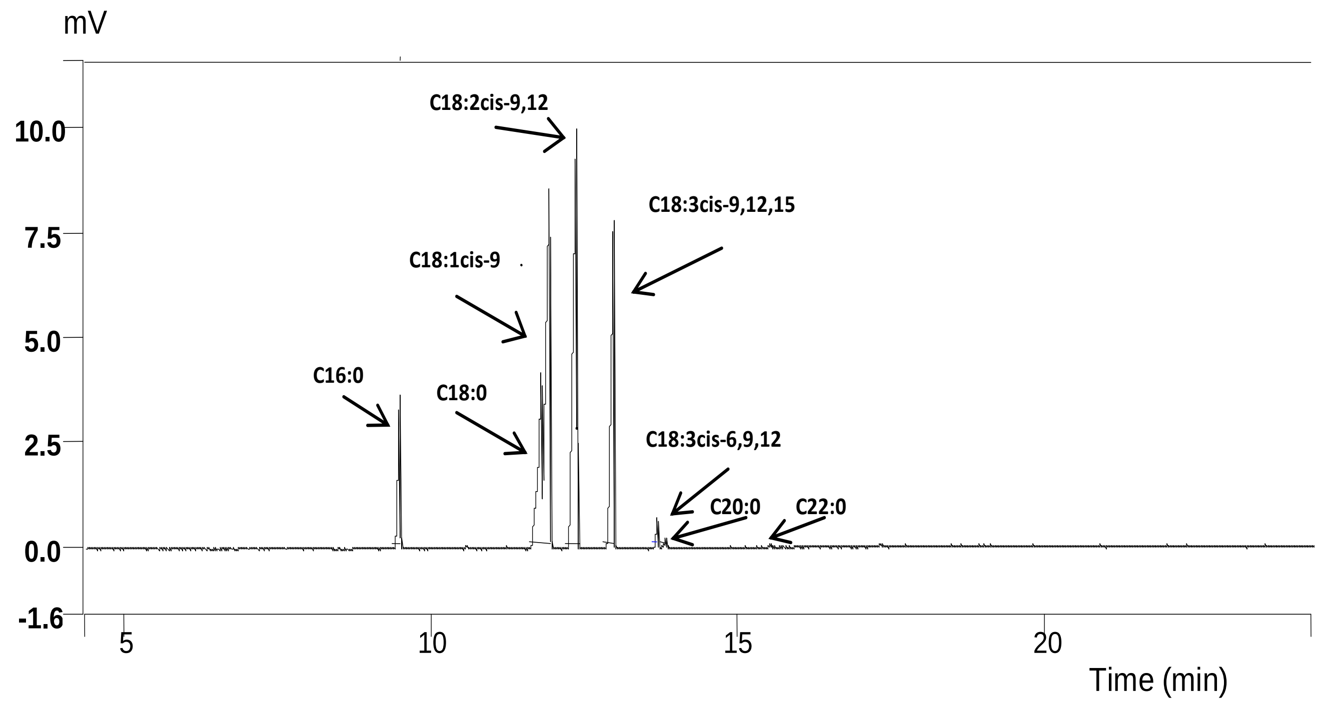

Figure 1. Chromatographic fatty acid profiles of 'venadillo' (*Swietenia humilis* Zucc.) seed oil.

Table 3. Composition of fatty acids in 'venadillo' (*Swietenia humilis* Zucc.) seed oil from trees in Culiacan, Mexico.

Fatty acid (%)	Tree					
	1	2	3	4	5	6
C16:0	6.86 ± 0.24	6.90 ± 0.23	6.23 ± 0.40	7.20 ± 0.80	7.28 ± 0.04	4.99 ± 0.13
C18:0	9.47 ± 1.37	8.32 ± 0.41	11.88 ± 1.19	13.71 ± 3.85	12.27 ± 1.14	12.72 ± 0.40
C18:1cis-9	29.11 ± 0.60	31.60 ± 0.67	25.85 ± 0.40	31.90 ± 5.66	29.80 ± 2.11	27.37 ± 1.21
C18:2cis-9,12	28.72 ± 0.67	28.87 ± 1.04	31.54 ± 0.93	27.20 ± 1.30	31.07 ± 0.30	31.51 ± 0.80
C18:3cis-9,12,15	19.41 ± 0.96	18.03 ± 0.25	18.18 ± 0.25	13.65 ± 1.37	13.48 ± 1.10	17.15 ± 0.47
C18:3cis-6,9,12	1.12 ± 0.10	0.98 ± 0.05	1.01 ± 0.09	1.10 ± 0.18	1.08 ± 0.13	0.91 ± 0.04
C20:0	0.35 ± 0.05	0.39 ± 0.01	0.45 ± 0.04	0.32 ± 0.13	0.18 ± 0.19	0.51 ± 0.04
C22:0	0.18 ± 0.02	014 ± 0.01	0.10 ± 0.09	0.14 ± 0.13	0.05 ± 0.09	0.07 ± 0.06

Values are given as mean ± standard deviation (n=3)

neuropathies. The same fatty acids increase from 5 to 15% the HDL-cholesterol level in plasma blood by a daily consumption of 0.7 to 1 g of EPA/DHA rate (Harwood and Yaqoob, 2002; Dubois et al., 2007).

The linoleic acid is precursor of the araquidonic acid (C20:4; omega 6), which in addition to the DHA help in the physical and mental development of children during the first stages of growth (Valenzuela and Nieto, 2001; Harwood and Yaqoob, 2002; Dubois et al., 2007).

In comparison with other commercial oils, 'venadillo' seed oil has higher α-linolenic content (16.65%) than olive, corn, soybean and sunflower oils whose content is 0.6, 1.0, 7.8, and 0.5%, respectively. The γ-linolenic acid (C18:3, cis-6,9,12; omega-6), which is a fatty acid that reduces cholesterol levels in blood, is absent in the commercial oils, while in 'venadillo' oil is present at 1.03% (Dubois et al., 2007).

Conclusion

The 'venadillo' oil showed physicochemical characteristics directly correlated with its content and rate of fatty acids. Due to its high content of unsaturated fatty acids and specially the polyunsaturated fatty acids, 'venadillo' seed oil could be used as a nutritional supplement to reduce blood triglyceride and cholesterol levels in patients with a high risk to suffer cardiovascular diseases.

Table 4. Saturated, unsaturated and polyunsaturated fatty acids in 'venadillo' (*Swietenia humilis* Zucc.) seed oil from trees in Culiacan, Mexico.

Fatty acid (%)	Tree					
	1	**2**	**3**	**4**	**5**	**6**
Saturated	16.85	15.74	18.65	21.38	19.78	18.30
Monounsaturated	29.11	31.60	25.85	31.90	29.80	27.37
Polyunsaturated	49.26	47.88	50.73	41.95	45.63	49.57

ACKNOWLEDGEMENTS

We appreciate the Council for Science and Technology in Sinaloa, the Mexican National Council for Science and Technology and the government of Sinaloa for the funds provided for this research. We also appreciate the technical support provided by Eduardo Sanchez-Valdez and Werner Rubio-Carrasco.

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