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Extraction and Chemical Composition of Seed Kernel Oil from *Irvingia smithii* of Congo Basin

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Abstract: This study is part of a wider program on the development of oilseeds in the Congo Basin and its aim was to contribute to the knowledge of *Irvingia smithii* kernel by studying his chemical composition following the example of those of *Irvingia gabonensis* and *Irvingia wombulu*. *Irvingia smithii* kernel, like those of *Irvingia gabonensis* and *Irvingia wombulu* is multipurpose, however, less known than the latter. The assessment of oilseeds of the kernel of *Irvingia smithii* showed that it is oleaginous with fat contents of about 55%. The fatty acid profile established by gas chromatography showed that the lauric acid content is higher than that of myristic acid (% C12: 0>% C14: 0) and both have a percentage of the total fatty acid content of nearly 90%. Palmitic acid (C16: 0), the third major constituent has nearly 5%. Oleic (C18: 1) and capric (C10: 0) acids have significant levels and palmitoleic (C16: 1) and stearic (C18: 0) acids are to trace. Triacylglycerol profile established by liquid chromatography coupled to the Evaporative Light Scattering Detector (ELSD) has three major TAG (% LaLaM >% LAMM >% LaLaLa), one minor TAG (MMM) and two TAG to trace (CLaLa and MMP). Fats of *Irvingia smithii* studied have levels of unsaponifiables ranging from 1.25 to 2.97% with the major components such as beta-sitosterol (36%) and stigmasterol (18%). For macronutrients, the most abundant element is Magnesium While the Iron is the least abundant with the following decreasing profile: Mg>P>Ca>Fe. Spectrometric assessment of color led to the remarkable presence of the peaks relating to the absorption of carotenoids and chlorophyll pigments located between 630 and 670 nm.

Keywords: Congo basin, fatty acid, *Irvingia smithii*, nutrients, oil content, triacylglycerol, unsaponifiable

INTRODUCTION

With about 235 million ha, the tropical forests of Central Africa, in addition to wood, abound of great potentialities in non-woody forest products. However most of these products are still sold outside official circuits, which do not make it possible to give a sufficient attention to their transformation and quality. However some of these products are subject to a more extensive trade and come to supply international markets in full growth. This is the case of *Irvingia gabonensis* and *Irvingia wombulu* whose market is estimated at approximately 50 million $EU of turnover (Lapido and Boland, 1994). The Irvingiaceae kernels are therefore part of the Non-timber forest products whose economic and food importances appear undeniable. But, despite their importance, the Irvingiaceae do not benefit from a good valorization and exploitation on a large scale. It should be noted that the Irvingia has six species in the Congo Basin, namely: *Irvingia gabonensis*, *Irvingia grandifolia*, *Irvingia smithii*, *Irvingia wombulu*, *Irvingia excelsa*, *Irvingia robur* (Makita-Madzou, 2000), whose only *Irvingia gabonensis* and *Irvingia wombulu* species appear to be

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well known and are the subject of several transactions and some physicochemical studies (Silou *et al*., 2004; Matos *et al*., 2009).

After having devoted an article on fat extracted from the kernel of *Irvingia wombulu* (Silou *et al*., 2011), we present here the study relating to the extraction and the chemical composition of the fat of the kernel of *Irvingia smithii*, for the promotion of its food use. *Irvingia smithii* which is the subject of the present study is a large forests tree which can rich 20 m in height, preferably along the rivers. It is a tree widely distributed in the Gulf of Guinea and its surface of distribution extends from Nigeria to Angola. This study is part of a wider program on the development of oilseeds in the Congo Basin and aiming like main aim: To contribute to the knowledge of the kernel of *Irvingia smithii* following the example of those of *Irvingia gabonensis* and *Irvingia wombulu*.

MATERIALS AND METHODS

This study was led to the laboratory of Physical Chemistry of the multidisciplinary team of Food and Nutrition Research of Marien Ngouabi University and in partners laboratories: Laboratory of Chemistry of Heterocycles and Carbohydrate, Chemistry of Essential Oils, Campus des Cezeaux, Blaise Pascal University of Clermont Ferrand, (France) and the laboratory of engineering and biomolecule of the ENSAIA-INPL, Vandoeuvre-lès-Nancy (France) for the period of March 2011 to October 2011.

Samples: *Irvingia smithii* fruits were plucked directly from several trees of Dzoumouna forest situated at about 20 km south of the Brazzaville, capital of Congo. The kernels were removed from their tenacious leathery coat, dried and finely ground into powder.

Fat extraction:

Soxhlet method: The dried and crushed kernels were introduced into a Soxhlet extractor. After 5 h extraction with hexane as solvent, the extract was dried with sodium sulfate. The solvent was evaporated in a rotary vacuum evaporator and the solvent traces were eliminated by drying oil in an oven at 103°C for 6 h.

Bligh and Dyer (1959) method: Dried and crushed kernels were homogenized with chloroform. The addition of the mixture of methanol/water (1:1, v/v) lead to two phases: aqueous phase (methanol-water) and organic phase (chloroform).

Fat was recovered from the solvent organic phase by evaporating off the solvent and residual was removed by drying in an oven at 103°C for 6 h.

Folch method (Folch *et al*., 1957): Dried and crushed kernels were homogenized with chloroform/methanol (2:1, v/v). The addition of NaCl solution (20%) leads to two phases. Fat was recovered from the organic phase by evaporating off the solvent and residual solvent was removed by drying in an oven at 103°C for 6 h.

Determination of fatty acid composition: After the trans esterification of fatty acids by sodium methylate 1 N in methanol at ambient temperature during 2 min and under agitation, the methyl ester fat were analysed on a Hewlett-Packard gas chromatograph model 5890, equipped with a FAME column (100×0.25 mm, 0.25 µm), programming from 140°C (5 min) -240°C at 4°C/15 min hold.

Hydrogen as carrier gas (0.7 mL/min); injection in split mode (1:40); injector and detector temperature, 280 and 300°C, respectively. FAMEs were identified by comparison of retention times with authentic standards and quantification was performed by internal normalization.

Determination of TAG profiles: Triacylglycerol (TAG) profile was obtained by High Performance Liquid Chromatography (Heron *et al*., 2007). The chromatographic system consisted of a model LC-6A Pump (Shimadzu'Kyoto, Japan) Rheodyne loop a model 7125 injector valve with a 10 µL loop (Rheodyne, Cotati, CA, the United States) and a model Sedex 75 Light-scarttering detector (Sedere, Alfortville, France). The nebulizing gas was air set 3, 5 bar, the evaporation temperature was set 37°C and the gain (PM) at 11. The column temperature was controlled using an igloo-cil column oven (Cluzeau, Sainte-Foy-la-Grande, France) and set at 30°C evaporative detector with diffusion of light (Sedere Sedex 75).

TAG were separated at 20°C using a Kromacil C18 (5 µm), 250×4.6 mm column (Part Number KR5C18-25QS mfg # 806610) and was eluted from the column with a mixture of acetonitrile/dichlorom ethane (70/30-40/60). Chromatograms were recorded using an Azur (v 3.0), data acquisition software (Datalys, Saint Martin d'Heres, France).

Determination of unsaponifiable fraction composition (norme NF T 60-205-2): The unsaponifiable fraction of the fat was analyzed on an Agilent gas chromatograph Model 7890, coupled to an Agilent MS model 5975C, equipped with a DB5 MS column (20 m×0.18 mn, 0.18 µm) programming from 50°C (3.2 min) -320°C at 8°C/min, 3 min hold. Helium as carrier gas (1.0 mL/min); injection split mode (1:150); injector and detector temperature, 320 and 280°C, respectively. The MS working in electron impact mode at 70 eV; ion source temperature, 230°C; mass spectra data were acquired in the scan in m/z range 33-450.

Thermal behavior: The thermal property of the oil samples was investigated by differential scanning calorimetry using a Perkin-Elmer Diamond DSC

(Norwalk, USA). The instrument was calibrated using indium and zinc. The purge gas used was 99.99% nitrogen with a flow rate of 100 mL/min and a pressure of 20 psi. Sample weights ranged from 5-7 mg and were subjected to the following temperature program: Frozen oil sample was heated at 50°C in an oven until completely melted. Oil sample was placed in an aluminum volatile pan and was cooled to -50ºC and held for 2 min, it was then heated from -50 to 50°C at the rate of 5°C /min (normal rate) (Che Man and Swe, 1995) and held -50°C isotherm ally for 2 min and cooled from -50 to 50°C at the rate of 5°C/min. The heating and cooling thermo grams for the normal and the fast (hyper DSC) scan rates were recorded and the onset, peak and offset temperatures were tabulated. These values provide information on the temperature at which the melting process starts, the temperature at which most of the TAG have melted and the complete melting temperature of the oil, respectively.

Proximate analysis of *Irvingia smithii* seed: Moisture, crude protein (micro-Kjeldahl), crude fiber and oil (Soxhlet) contents were determined using the methods described by Pearson (1976), whereas the ash content was determined using the method of Pomeranz and Meloan (1994) and total carbohydrate was determined by difference. All determinations were done in triplicate.

Minerals: The minerals were determined by atomic absorption spectrophotometry. One gram samples, in triplicate, were dry ashed in a muffle furnace at 550ºC for 8 h until a white residue of constant weight was obtained. The minerals were extracted from ash by adding 20.0 mL of 2.5% HCl, heated in a steam bath to reduce the volume to about 7.0 mL and this was transferred quantitatively to a 50 mL volumetric flask. It was diluted to volume (50 mL) with deionised water, stored in clean polyethylene bottles and mineral contents determined using an atomic absorption spectrophotometer (Perkin- Elmer, Model 2380, USA). These bottles and flasks were rinsed in dilute hydrochloric acid (0.10 M HCL) to arrest microbial action, which may affect the concentrations of the anions and cations in the samples. The instrument was calibrated with standard solutions.

Spectrometric evaluation of color: Place in a 10 mL volumetric flask, 5 mL of fat previously melted at 40°C, complete to volume with cyclohexane, the resulting solution is filtered. We measure the absorption between 400 and 700 nm at the maxima of the absorption of the main pigments of vegetable oils: carotenoids, chlorophyll (Helmy, 1990), using a spectrophotometer.

Statistical analysis: Values represented are the means and standard deviations for three replicates. Statistics were processed using Excel Version 8.0 software, ChemWindow 6.0 and the XLSTAT 2000.6 software, which is a Microsoft Excel add-in (www.xlstat.cm).

RESULTS AND DISCUSSION

Fat content and fatty acid composition: Fats of 11 samples of seed kernels of *Irvingia smithii* (corresponding to 11 different trees) were studied. The fats studied were obtained by three different methods of extraction using organic solvents: the standard Soxhlet method (SXL), the method of Bligh and Dyer (BD) and the method of Folch simplified (FL) (Silou *et al*., 2011). The fat content and fatty acid compositions are reported in Table 1.

Table 1: Fat content and fatty acid composition of *Irvingia smithii* kernel oil extracted by different methods

Samples	Fat content (%)	C10: 0	C12: 0	C14: 0	C16: 0	C16: 1	C18: 0	C18: 1	C18: 2	R*
Soxhlet										
Is 20	49.54 (0.54)	2.23	42.74	41.63	5.77	1.08	0.61	4.35	0.70	0.97
Is 21	51.89 (0.27)	3.01	48.11	38.26	4.94	0.73	0.58	3.17	0.47	0.79
Is 22	50.02 (0.24)	2.56	45.76	40.27	5.36	0.71	0.58	3.50	0.53	0.88
Is 23	49.54 (0.48)	2.76	48.48	39.27	4.70	0.59	0.54	2.64	0.42	0.81
Is 24	53.74 (0.28)	3.24	51.04	35.92	4.23	0.80	0.41	3.00	0.61	0.70
Is 25	54.28 (0.41)	2.94	46.66	37.41	5.04	1.04	0.61	4.71	0.67	0.80
Is 26	54.54 (0.32)	3.66	52.04	34.59	4.26	0.79	0.34	2.85	0.59	0.66
Is 1 RC	54.05 (0.30)	3.81	54.54	33.04	4.37	0.73	0.59	2.84	0.49	0.61
Is 2 RC	54.13 (0.38)	3.67	51.85	33.84	3.78	0.71	0.44	3.18	0.51	0.65
Is 3 RC	53.92 (0.22)	4.31	55.02	30.47	4.21	0.64	0.41	2.89	0.52	0.55
Is 4 RC	52.22 (0.31)	4.39	54.50	31.23	3.44	0.52	0.42	3.13	0.58	0.57
Bligh and dyer										
Is 20	39.67 (0.67)	1.98	43.16	42.40	5.87	0.87	0.58	3.71	0.59	0.98
Is 21	48.30 (0.03)	2.80	47.02	39.21	5.03	0.79	0.55	3.31	0.53	0.83
Is 22	40.03 (0.17)	3.39	48.99	38.22	5.04	-	4.35	-	-	0.78
Is 23	43.37 (0.76)	2.33	46.60	40.99	5.06	0.58	0.54	2.78	0.46	0.88
Folch										
Is 20	45.21 (0.37)	2.23	43.94	42.08	5.52	0.86	0.55	3.50	-	0.96
Is 21	48.99 (0.22)	2.94	48.21	38.62	4.84	0.72	0.53	3.00	0.46	0.81
Is 22	44.55 (0.34)	2.57	46.69	40.22	5.14	0.62	0.51	3.09	0.47	0.86
Is 23	47.39 (0.09)	2.46	47.51	40.77	4.90	0.58	0.51	2.67	-	0.85

*: R = [(% C14: 0) / (C12: 0)]

Table 2: Fatty acid profile of *Irvingia smithii* (Is 21) kernel oil obtained with two solvents commonly used in food agro processing

	Fatty acid composition (%)	
Fatty acids	Hexane	Cyclohexane
C10: 0	3.15	3.01
C12: 0	47.50	48.11
C14: 0	36.57	36.26
C16: 0	4.71	4.94
C16: 1	0.78	0.73
C18: 0	0.56	0.58
C18: 1	3.76	3.17
C18: 2	0.62	0.47

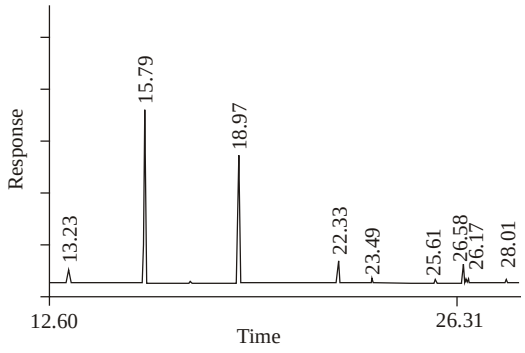

Fig. 1: Fatty acid profile of *Irvingia smithii* kernel oil (GC)

The very low values of standard deviations of the fat content (Table 1) indicate a reproducible extraction on each homogeneous sample of the plant matter used. This content which varies from 40 to 54% is well below those encountered for *Irvingia gabonensis* and *Irvingia wombulu* (Silou *et al*., 2011). *Irvingia smithii* is less oleaginous than these two oilseed species of *Irvingia* already studied regardless of the extraction solvent or method used. However for each sample, the Soxhlet extract a little more fat than the other two methods, but the difference is small.

Whatever the extraction method used, lauric acid (C12: 0) (42.74-55.02%) is the first major constituent of the fat of *Irvingia smithii* followed by mirystic acid (C14: 0) (30.47-42.40%). In this, it resembles more the fat of *Irvingia wombulu* with R<1 (Silou *et al*., 2011). Palmitic acid (C16:0) comes in third position with levels of the order of 5% and the acids oleic (C18: 1, 2.0-4.5%) and caprylic (C10: 0, 2.0, -3.5%) are more abundant than in *Irvingia gabonensis* and *Irvingia wombulu* (Silou *et al*., 2011). Acids stearic (C18: 0) and palmitoleic (C16: 1) are to trace. *Irvingia smithii* fat differs much from those of *Irvingia gabonensis* and *Irvingia wombulu* studied by Silou (2011) by a lower content in the seed by more significant amounts of C18: 1 and C10: 0. This should lead to an fatty acid profile a bit more complex:

% C12: 0>% C14: 0>% C16: 0>% C18: 1>% C10: 0 (Fig. 1)

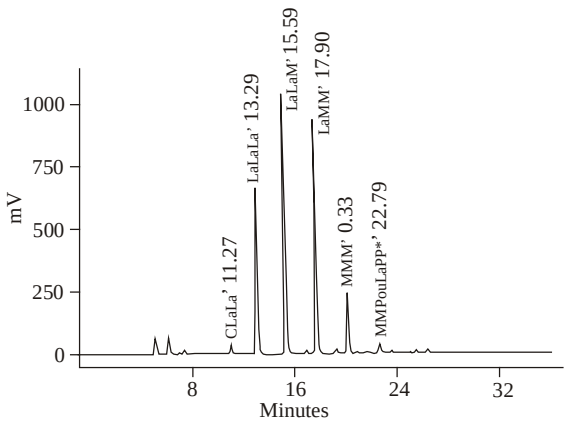

Fig. 2: Triacylglycerol profile of *Irvingia smithii* kernel oil (HPLC)

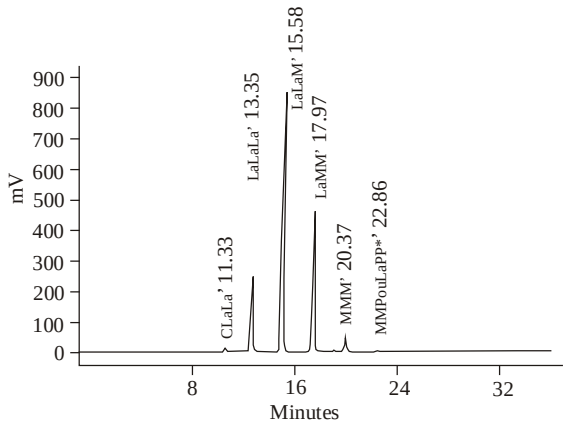

Fig. 3: Triacylglycerol profile of *Irvingia wombulu* (HPLC) (Silou *et al*., 2011)

The extraction of the fat of the same sample made with the soxhlet, as a control, by using the two solvents most commonly used in the food agro processing leads to a perfect similarity of fats obtained (Table 2).

Triacylglycerol (TAG) profiles of the oils studied: Fats of *Irvingia smithii* studied, whatever the extraction method used show a stable profile in TAG. This profile is qualitatively and quantitatively similar to that of the fat of *Irvingia wombulu* (Fig. 2 and 3). However trimyristin (MMM) present at trace levels in the fat of *Irvingia wombulu*, has a content of around 10% in the fat of *Irvingia smithii*. It is in the end the following profile-type:

% LaLaM>% LAMM>% LaLaLa>% MMM (Fig. 2)

Composition of the unsaponifiable fraction: The composition of the unsaponifiable fraction of fats of *Irvingia smithii* is given in Table 3.

Table 3: Composition of the unsaponifiable fraction of *Irvingia smithii* kernel oil

	Sample 1 (Is 21) *Irvingia smithii*	Sample 2 (Is 27) *Irvingia smithii*	Sample 3 (Is 22) *Irvingia smithii*
Unsaponifiable content (%)	1.36 (0.12)	2.97 (0.33)	1.25 (0.25)
Composition (%)			
NI	7.83	14.38	-
NI	7.52	13.76	-
Phytol	-	0.35	0.56
Squalene	0.22	0.16	0.42
NI	0.98	0.87	0.82
Bis- (octylphényl) amine	-	0.21	-
Campestérol	5.92	4.79	9.25
Stigmastérol	12.68	9.75	18.97
NI	-	0.52	1.05
Bêta-sitostérol	25.09	17.55	36.55
Fucostérol		2.01	4.43
Cycloartenol	3.23	0.95	5.70
Cyclolaudenol	2.93	1.69	1.99
NI	19.31	2.32	12.65

NI: Not identified

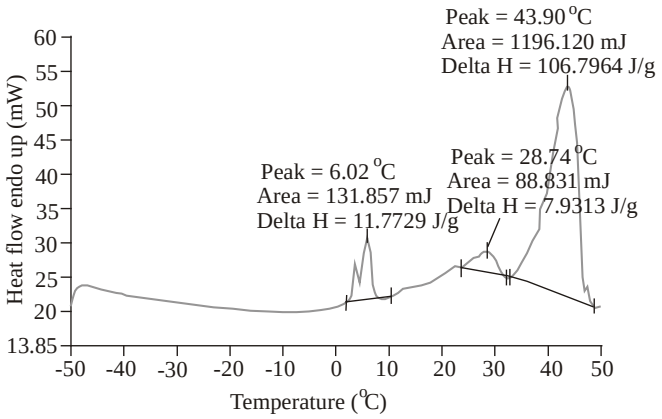

Fig. 4: Thermogram of *Irvingia smithii* kernel oil recorded by Differential Scanning Calorimetry (DSC)

Fats of *Irvingia smithii* studied have unsaponifiable matter contents ranging from 1.25 to 2.97% (Table 3). Compared to fat of *Irvingia gabonensis* and *Irvingia wombulu* (Silou *et al*., 2011), these levels are in the same order of magnitude and slightly exceed the 2%, maximum content of unsaponifiables materials commonly found in vegetable oils.

The examination of Table 3 shows the presence of hydrocarbons to the state of trace (0.16-0.42%) represented mainly by squalene. The beta-sitosterol (17.55-36.55%) is the major component followed by stigmasterol (18.97%) and a non-identified compound (12.65%) for Is 22 sample. We also identified the presence of campesterol, cycloartenol, fucosterol, Cyclolaudénol. However the fat of the three samples of *Irvingia smithii* studied, all harvested in the forest of Dzoumouna, highlight instability of the composition of unsaponifiable materials of a sample to another.

Thermograms of fats obtained by differential scanning calorimetry: The fats obtained from *Irvingia smithii* seed kernel were solid at ordinary temperature. Differential Scanning Calorimetry (DSC) is suitable to determine these physical properties. The thermo grams obtained are shown in Fig. 4 and the corresponding parameter values are shown in Table 4.

Table 4: Data of thermal behavior of *Irvingia smithii* kernel oil by Differential Scanning Calorimetry (DSC)

		Attribution	
Parameters	Oil (Is)	Insaturation	TAG
Peak 1 (°C)	6.02	100	-
ΔH (J/g)	11.77		
Peak 2 (°C)	28.74	000	LaLaLa/MMM
ΔH (J/g)	7.93		
Peak 3 (°C)	43.90	000	LaMM/LaLaM
ΔH (J/g)	106.80		

These assignments were made on the basis of the diagram proposed by Berger and Akehurst (1996) drawn up after crossing the results of TLC and GC fractioning and the DSC of the identified fractions and the total oils of palm, cotton seed and soy. It assigns the melting point range 20 to 50°C to the TAGs of unsaturation 000 and the range -20 to 20°C to TAGs of unsaturation 100.

The scrutiny of the data in the Table 3 shows the presence of three peaks that appear at 6.02°C with an enthalpy of fusion (ΔHf) of 11.77 J/g, at 28.74°C with an enthalpy of fusion (ΔHf) of 7.93 J/g and at 43.90°C with an enthalpy of fusion (ΔHf) of 106, 80 J/g. These three peaks correspond to saturated fatty acids. The peak that appears at 43.90°C which corresponds to

Table 5: Proximate analysis (g/100 g dry weight) of *Irvingia smithii* seed kernel

	Obtained values[a] (M±S.D.)		Reported values[b]		
Characteristic	Sample 1	Sample 2	*Cucurbita* spp (courge)	*Arachis hypogeae*	*Glucine max* (soja)
Moisture content (%)	5.81±0.35	6.11±0.35	5.5	6.5	9.5
Crude protein[c] (%)	19.75±2.51	20.22±3.42	23.4	23.2	33.7
Fats/oils (%)	50.25±2.11	54.52±2.61	46.2	44.8	17.9
Crude fiber (%)	14.08±2.49	12.34±2.77	-	-	-
Ash content (%)	3.53±0.05	2.46±0.15	3.4	2.5	5.0
Total carbohydrate[d] (%)	20.66±0.78	16.69±0.25	21.5	23.0	33.9

[a]: M±S.D. mean±standard deviation; [b]: FAO (1970); [c]: Crude protein = N (%) x 6.25; [d]: Carbohydrate obtained by difference

Table 6: Mineral elemental composition of *Irvingia smithii* seeds

	Composition (mg/100 g) of seed		
Mineral elements	Sample 1 Is 20	Sample 2 Is 21	Sample 3 Is 22
Calcium, Ca	30.07±1.39	31.28±0.87	28.56±1.55
Phosphorus, P	423.24±1.05	430.13±1.91	416.13±1.54
Magnesium, Mg	502.44±4.53	442.86±5.01	534.60±3.58
Fer, Fe	3.18±0.09	3.11±0.13	3.24±0.07

Values are mean±S.D. of triplicate determinations

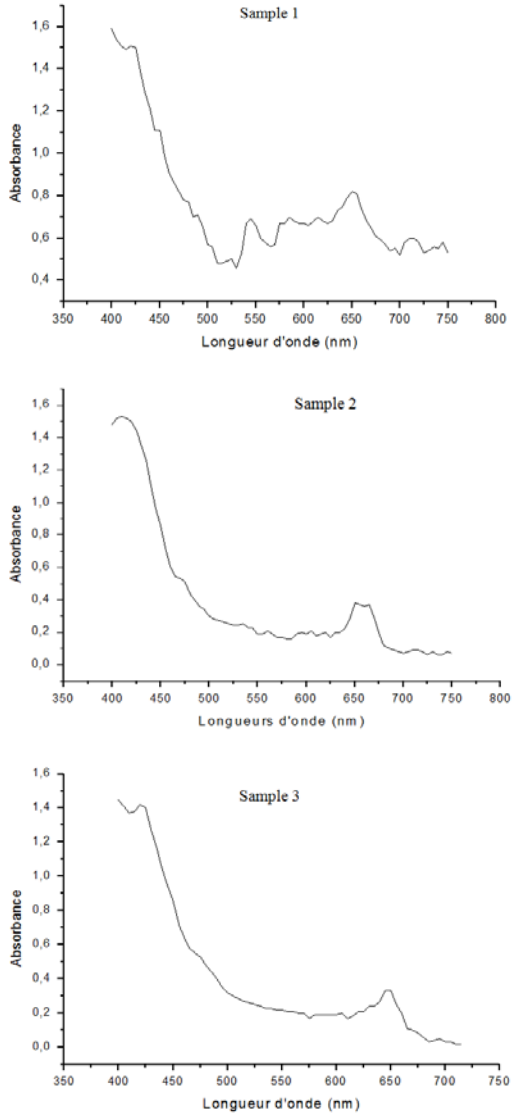

Fig. 5: The absorption spectra in the visible of three samples of *Irvingia smithii* kernel oil of Congo (5 g of oil in 10 mL of cyclohexane)

the largest energy ΔH = 106.80 J/g is attributed to the melting of two major mixed TAGs: LaMM and LaLaM (Silou *et al*., 2011). By difference, we attribute the second peak appearing between 20 and 30°C for other components that remain saturated and which are both homogeneous TAGs LaLaLa and MMM.

Proximate analysis of *Irvingia smithii* L. seed kernel oil: Results obtained showed that the seeds contained 5.81 to 6.11% moisture, 50.25 to 54.52% crude oil, 19.75 to 20.22% crude proteins, 16.69 to 20.66% carbohydrate (by difference), 12.34 to 14.08% crude fiber and 2.46 to 3.53% ash (Table 5). The high percentage of oil makes this seed a distinct potential for the oil industry.

Crude protein is slightly lower than that of the kernel of *Irvingia gabonensis*, 25.75% (Silou *et al*., 2004), of seeds of squash (23.4%) and peanuts (23.2%), but by far less that of Soybean (33.7%). According to Cheftel *et al*. (1977), this level of content allows to take charge of the activities for growth and maintenance. Fiber content is significant with an average of 14.8%. On the one hand, this allows a high power of water retention and on the other hand the increase of the volume of the food bowl stimulating intestinal motility and preventing constipation (Herd *et al*., 1984). The ash content is lower than that of soybean, but remains higher than that of squash (3.4%) and peanuts (2.5%).

Minerals: The *Irvingia smithii* L. seeds contained significant amount of important minerals (Table 6). The Magnesium concentration (442.86±5.01 to 534.60±3.58 mg/100 g dry mater) was the highest, followed in descending order by Phosphorus (416.13±1.54 to 430.13±1.91 mg/100 g dry mater), Calcium (28.56±1.55 to 31.28±0.87 mg/100 g dry mater), Fer (3.11±0.13 to 3.24±0.07 mg/100 g dry mater). Calcium and Magnesium plays a significant role in photosynthesis, carbohydrate metabolism, nucleic acids and binding agents of cell walls (Russel, 1973). Calcium assists in teeth development (Brody, 1994).

Magnesium is essential mineral for enzyme activity, like calcium and chloride; magnesium also plays a role in regulating the acid-alkaline balance in the body. Phosphorus is needed for bone growth, kidney function and cell growth. It also plays a role in maintaining the body's acid-alkaline balance (Fallon and Enig, 2001). Iron is important in biochemical functions such as transportation and storage of oxygen, electron transport and enzymatic reactions, oxidation or reduction of substrate.

Spectrometric evaluation of color: The measurement of absorption in the visible between 400 and 700 nm provides information on the intensity of the color of the oil or fat studied. The Fig. 5 represents the absorption spectra in this area of the visible of three samples of *Irvingia smithii* of Congo Brazzaville.

Examination of these figures shows that the three spectra are quite similar and exhibit the light absorption maxima of carotenoids around 425 nm and around 480 nm and two very distinctive absorption maximum corresponding to the chlorophyll pigments between 630 and 670 nm. Mampouya (2006) also identified this double peak in the same areas in safou pulp oil. These results corroborate those of Helmy (1990) who, by studying the oils extracted from seeds of citrus and cucurbits, identified absorption maxima at 400, 425, 455, 480 nm for carotenoids, at 610, 670 nm for chlorophylls (Silou *et al*., 2004). The absorption spectrum of the sample 1 (Is 20) has a maximum around 550 nm. This peak may well correspond to the unknown pigment than Helmy (1990) located at 525, 570, 575 nm. All this allows us to conclude that the fat of *Irvingia smithii* contains carotenoids and chlorophylls which are majority and confirm the slightly greenish coloration observed to the naked eye.

CONCLUSION

The study of fats from the kernel of *Irvingia smithii* was done by three different methods of extraction using organic solvents: the standard method using soxhlet, the method of Bligh and Dyer and Folch method simplified, to determine the fat content of different samples studied. This study found that: The kernels of *Irvingia smithii* are oleaginous with fat contents of approximately 55% after 6 h of Soxhlet extraction in hexane. Whatever the sample, the heat extraction by soxhlet method is more profitable than the extraction by the Folch method and the latter more profitable than the method by Bligh and Dyer (1959). The lauric acid content is greater than that of myristic acid (% C12: 0>% C14: 0) and both have a percentage of the total fatty acid content of nearly 90%. Palmitic acid (C16: 0), the third major constituent has nearly 5%. Oleic (C18: 1) and capric (C10: 0) acids have significant levels and palmitoleic acid (C16: 1) and stearic (C18: 0) are to trace. The fat of *Irvingia smithii* is saturated and can be used in industrial frying. Magnesium and phosphorus are the most abundant macro elements of this fat. Spectrometric evaluation led to the remarkable presence of peaks relating to the absorption of carotenoids and chlorophyll pigments located between 630 and 670 nm.

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REFERENCES

Berger, K.G. and E.E. Akehurst, 1996. Some applications of differential thermal analysis of oils and fats. J. Food Technol., 1: 237-247.

Bligh, L.G. and A.J. Dyer, 1959. A rapid method for total lipid extraction and purification. Can. J. Biochem., 37: 911-917.

Brody, T., 1994. Nutritional Biochemistry. 2nd Edn., Academic Press, San Diego, CA, pp: 761-794.

Che Man, Y.B. and P.Z. Swe, 1995. Thermal analysis of failed-batch palm oil by differential scanning calorimetry. J. Am. Oil Chem. Soc., 72(12): 1529-1532.

Cheftel, J.C., H. Cheftel, P. Bejancon, 1977. Introduction to Biochemistry and Food Technology and Technical Documentation (French), Lavoisier, Paris, 2.

Fallon, S. and M.G. Enig, 2001. Nourishing Traditions. The Cookbook that Challenges Policitally Correct Nutrition and the Diet Dictocrats, NewTrends, Washington, DC., pp: 40-45.

Folch, J., M. Lee and G.H.S. Stanley, 1957. A simple method for the isolation and purification of total lipides from animal tissues. J. Biol. Chem., 226(1): 497-509.

Helmy, E.H., 1990. Studies on the pigments of some citrus, prune and cucurbit seed oils when processed with or without cotton seed oil. J. Amer. Oils Chem. Soc., 67(6): 376-380.

Heron, S., M.G. Maloumbi, M. Dreux, E. Verette and A. Tchapla, 2007. Method development for a quantitaive analysis performed without any standard using an evaporative light scattering detector. J. Chromatogr. A., 1161: 152-156.

Lapido, D.O. and D.J. Boland, 1994. Trade in Irvingia Kernels. In: Lapido, D.O. and Boland (Eds.): Proceedings of the International Workshop on Irvingia in West Africa. International Centre for Research in Agroforestery (ICRAF) Nairobi, Kenya.

Makita-Madzou, J.P., 2000. Report of Congo. IPGRI. Program of forest genetic resources in Africa south of the Sahara. Eyog Matig, O., O. Gandé Gaoué and B. Dossou (Eds.), Food Tree Species Network (French). Minutes of the First Meeting of the Network, CNSF Ouagadougou, Burkina Faso, pp: 11-13.

Matos, L., J.M. Nzikou, A. Kimbonguila, C.B. Ndangui, N.P.G. Pambou-Tobi, A.A. Abena, T.H. Silou, J. Scher and S. Desobry, 2009. Composition and nutritional properties of seeds and oil from terminalia catappa L. Adv. J. Food Sci. Tech., 1(1): 71-76.

Pearson, D., 1976. The Chemical Analysis of Foods. 7th Edn., R.K. Churchill Livingstone, Edinburgh, U.K., pp: 488-496.

Pomeranz, Y. and C. Meloan, 1994. Food Analysis: Theory and Practice. 3rd Edn., Chapman and Hall, New York, pp: 778.

Russel, E.W., 1973. Soil conditions and plant growth. Supergene Zone, M. Nedra, pp: 19 (In Russian).

Silou, T.H., S. Biyoko, S. Heron, A. Tchapla and M.G. Maloumbi, 2004. Physico-chemical characteristics and technological potentialities of Irvingia gabonensis seeds. Riv. Ital. Sostanze. Gr., 81: 49-57.

Silou, T., B.W. Loumouamou, S. Nsikabaka, T. Kinkela, M. Nzikou, P. Chalard and G. Figueredo, 2011. Contribution to the varietal delimitation of irvingia gabonensis and irvingia wombulu chemical comosition variability of fats extracted from kernels. J. Food Technol., 9(1): 36-42.