Journal of Food Research; Vol. 6, No. 3; 2017
ISSN 1927-0887 E-ISSN 1927-0895
Published by Canadian Center of Science and Education

Roasting Effect on the Nutritional and Cosmetic Potential of *Citrullus Lanatus* Kernels Oil

Séri S. Guédé[1], Grodji A. Gbogouri[1], Doudjo Soro[2], Kouamé K. Koffi[3], Kouakou Brou[1] & Bi Irié A. Zoro[3]

[1]Department of Food Sciences and Technology, Nangui Abrogoua University, Abidjan, Ivory Cost

[2]Laboratory of Industrial Processes of Synthesis of the Environment and the New Energies, Institut National Polytechnique Félix Houphouët-Boigny (INP-HB), Yamoussoukro, Ivory Cost

[3]Department of Natural Sciences, Nangui Abrogoua University, Abidjan, Ivory Cost

Correspondence: Séri S. Guédé, Department of Food Sciences and Technology, Nangui Abrogoua University, 02 BP 801 Abidjan 02, Ivory Cost. Tel: 2-254-932-0720. E-mail: s_guede@yahoo.fr

Received: January 28, 2017 Accepted: March 2, 2017 Online Published: March 20, 2017

doi: 10.5539/jfr.v6n3p11 URL: https://doi.org/10.5539/jfr.v6n3p11

Abstract

The objective of this study was to evaluate the effect of roasting on the nutritional and cosmetic potential of oil extracted from kernels of *C. lanatus*, which is one of the most widespread Cucurbitaceae species in Sub-Saharan Africa. The dried kernels (DKO) and roasted kernels (RKO) oils were extracted by cold press and hot using hexane. The physicochemical properties of these oils were evaluated. The results showed that *C. lanatus* roasted kernels were important sources of lipids (40.12 %) and protein (37.50 %). Oil extracted by press was of high quality, compared to that extracted by hexane. The study of the roasting effect revealed that the physicochemical characteristics of DKO and RKO oils were significantly different, with the exception of their specific gravity (≈ 0.9) and their refractive index (≈ 1.47). The absorbance of the two oils decreased in the range of UV-A and UV-B wavelengths. Both oils had low oxalates content (≈ 0.05 %) and were free of phytates and cyanogenic glycosides. All these features suggest that the roasted kernels oil of *C. lanatus* could be used in food and cosmetic industries.

Keywords: Sub-Saharan Africa, oleaginous cucurbit, roasting, pressing, kernel oil, physicochemical properties.

1. Introduction

C. lanatus (Thunb.) Matsum. & Nakai is a species of the Cucurbitaceae family (Schippers, 2000). It is widespread in rural and urban areas of Sub-Saharan Africa. It is mainly grown in savannah regions and in pre-forest areas. The *C. lanatus* seeds are important sources of lipids and proteins (Loukou et al., 2007; Gbogouri et al., 2011). *C. lanatus* oil is rich in linoleic acid which is an essential fatty acid (Olaofe et al., 2012; Gbogouri, Brou, Beugre, Gnakri, & Linder, 2013). This fatty acid gives it the nutritional and cosmetic values (Vermaak, Kamatou, Komane-Mofokeng, Viljoen, & Beckett, 2011).

Contrary to palm oil and palm kernel oil, shea (*Butyrospermum paradoxum*) and makore (*Tieghemella heckelii*) butters, cucurbits oils are not produced traditionally. It has been shown that cucurbits seeds are dried, roasted and then made into a paste which is solely used in the preparation of sauces (Zoro Bi, Koffi, & Djè, 2003; Zoro Bi, Koffi, Djè, Malice, & Baudoin, 2006). In addition, high levels of polyunsaturated fatty acids confer on cucurbits oils high instability; which leads to the decrease of their nutritional and cosmetic values (Loukou, Lognay, Baudoin, Kouame, & Zoro Bi, 2012). Therefore, they require special conditions of production and storage.

Roasting is often practiced in small-scale processing of oilseeds. It is a very important operation. It changes the physicochemical compositions of the seeds (McDaniel, White, Dean, Sanders, & Davis, 2012; Agarwal, 2014) and those of their oils (Anjum, Anwar, Jamil, & Iqbal, 2006; Sultana, Saleem, & Ambrat, 2011). It develops the colour of the seeds (Moss & Otten, 1989) and their flavour (Shimoda, Nakada, Nakashima, & Osijima, 1997). It destroys undesirable microorganisms and inactivates enzymes that alter the product during storage (Torlak, Sert, & Serin, 2013). It has been shown that the roasting of oilseeds, before extraction, in general improves the oxidative stability of their oils (Harhar et al., 2011).

Oil extraction by solvent is the most widely used method because its extraction yield is significantly higher than that of mechanical extraction. But its high cost and air pollution by solvents are obstacles for small processing

units. In addition, the high temperature affects the oil quality (Liauw et al., 2008). Extraction by cold press is carried out at low temperature and without a solvent intake; that could contribute to the preservation of the quality of the oil and improvement of its stability. Faced with the challenge of food security, extraction by cold press is a promising alternative (Nitiéma-Yefanova, Son, Yé, Nébié, & Bonzi-Coulibaly, 2012).

Roasting and cold pressing seem to be ways to overcome the rapid rancidity of cucurbit oil. Moreover, most biochemical data available on cucurbit oils concern those extracted from raw or dried kernels. However, in Sub-Saharan Africa, kernels of oleaginous cucurbits are usually roasted before being used in different ways (food, cosmetics, etc.). Thus, the lack of scientific data about roasted kernels properties does not allow to know the real potential of cucurbit seeds for the populations concerned. That is the reason why this study was carried out. Also, a study was conducted to evaluate the roasting effect on the nutritional and cosmetic potential of *C. lanatus* kernels oil, with a view to upgrading this oil in food and cosmetic.

2. Materials Studied

The biological material consisted of seeds of the *C. lanatus* variety named "bebu" (local name in Ivory Coast). It was identified on the basis of the seeds shape (flat and oval, thick and rough edge (Figure 1)). Sampling was produced in May 2015 by some farmers in the Dikodougou department (latitude 9°04'03.3"N, longitude 5°46'20.0"W) located in northern of Ivory Coast.

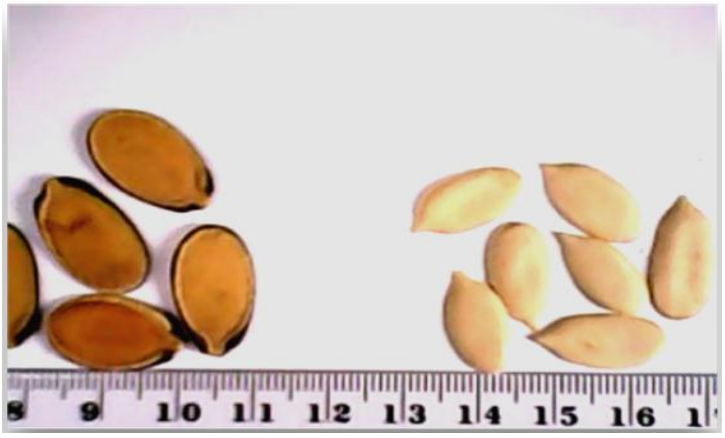

Figure 1. Seeds and kernels of *C. lanatus* grown in Ivory Coast

3. Methods

3.1 Preparation of Seeds

The *C. lanatus* seeds were sent to the genetics and plant breeding laboratory of the Natural Sciences Faculty (Nangui Abrogoua University, Ivory Coast). These seeds have been manually sorted and soaked in warm water for 15 min, and then shelled. The kernels were then washed with tap water and dried at 60 °C for 2 h in an oven (Model UFB 400, Memmert, Schwabach, Germany). Kernels were then divided into two batches. Batch n°1 consisted of dried kernels. Batch n°2 was composed of kernels roasted in a vessel, with continuous agitation, placed on a plate heated to 250 °C for 20 min. A quantity of each batch was ground using a micro-crusher (Laboratory crusher, Culatti AG, Zürich, Suisse) for further physicochemical analysis.

3.2 Oil Extraction

The oil was mainly extracted by cold pressing using a Komet screw press (Model CA 59 G, IBG Monforts Oekotec, Mönchengladbach, Germany) as described by Ferchau (2000). Crude oil was collected in a container and then centrifuged for 15 min using a centrifuge (Model Z 300 K, Hermle Labor-technik, Wehingen, Germany) set at 6000 rpm and 25 °C. To make a comparison of extraction methods, oil was also extracted according to AFNOR (Association Française de Normalisation) protocol (AFNOR, 1986) by using n-hexane in a behrostest Soxhlet-Extractor (Model R104 T-SK, Behr Labor-Technik, Düsseldorf, Germany). All oils were stored at 4 °C, protected from light, for further analysis.

3.3 Biochemical Analysis of Kernels

The moisture content was determined gravimetrically by drying in an oven (Model UFB 400, Memmert, Schwabach, Germany) set at 105 ℃ to reach a constant weight. The ashes, fiber, lipids and proteins were determined on the basis of the dry matter according to standard protocols described by the Association of Official Analytical Chemists (AOAC, 1990). The protein content was calculated from the total nitrogen using a conversion factor of 6.25. The carbohydrate content was calculated by difference:

$$Carbohydrates = 100 – (Proteins + Lipids + Fiber + Ashes) \quad (1)$$

The gross energy was calculated, according Atwater and Benedict (1902), by the following formula:

$$GE = [(Proteins \times 4) + (Lipids \times 9) + (Carbohydrates \times 4)] \times dry\ matter / 100 \quad (2)$$

where GE is the Gross Energy.

3.4 Physical Analysis of Oils

The specific gravity and the refractive index of oils were determined at 25 ℃ following protocols of International Union of Pure and Applied Chemistry (IUPAC, 1979) by using a pycnometer and a refractometer (Model AR200, Leica Microsystems, New York, USA), respectively. The viscosity of oils was determined at 25 ℃ by using a viscometer tube (AFNOR, 1986). The activation energy was determined according to method of Nzikou et al. (2009), based on the linearization of the Arrhenius equation. The UV-Visible spectra of the oil samples were determined by measuring the absorbance of a solution of oils in hexane (1 %: w/v) by using a UV-visible spectrophotometer (Model V-530, Jasco International, Tokyo, Japan) in the range of 200 to 600 nm (Besbes et al., 2004).

3.5 Chemical Analysis of Oils

The pH value of oil samples was determined at 25 ℃ following method described by Afane, Lando, Biyiti, Ossima, and Atchou (1997) by using a pH-meter (Model HI 8915, Hanna Instruments, Lingolsheim, France). Acid, peroxide, iodine and saponification values were determined according to AOAC protocols (AOAC, 1997). The ester value was determined by difference between the saponification and acid values. Unsaponifiable matter content was determined according to IUPAC protocol (IUPAC, 1979). Carotenoid and total phenols contents were determined according to colorimetric method described by Zoué, Bédikou, Gonnety, Faulet, and Niamké (2012) by using a UV-visible spectrophotometer (Model V-530, Jasco International, Tokyo, Japan). The oxalate and phytate contents were determined according to methods described by Inuwa, Aina, Gabi, Aimola, and Toyin (2011). The method used to determine the cyanogenic glycosides content was described by Onwuka (2005).

3.6 Statistical Analysis

All essays were performed in triplicate. The data were expressed as means ± standard deviation (SD). T test of Student was used to evaluate the roasting effect on the biochemical characteristic of kernels and the physicochemical properties of their oil. The analysis of variance (ANOVA) was used to determine the effect of the extraction method on the chemical indices of oil. When a significant difference was observed between the samples for a parameter, the ANOVA was supplemented by LSD (Least Significant Difference) test to identify the averages that are different. Statistical analysis was performed using Statistica 7.1 software (StatSoft, 2005) and statistical significance was measured at $P < 0.05$.

4. Results

4.1 Roasting Effect on the Biochemical Characteristic of C. Lanatus Kernels

Table 1 shows the biochemical composition of *C. lanatus* dried kernels and roasted kernels. Moisture and lipid contents, and gross energy are respectively 4.95 ± 0.39 %, 54.20 ± 0.64 % and 630.78 ± 3.45 kcal/100g in dried kernels against respectively 1.86 ± 0.20 %, 40.12 ± 0.28 % and 569.31 ± 1.88 kcal/100g in roasted kernels. Concerning ash, protein, fiber and carbohydrates, their contents are respectively 2.25 ± 0.03 %, 30.43 ± 0.28 %, 2.86 ± 0.31 % and 5.32 ± 114 % in dried kernels against respectively 3.93 ± 0.13 %, 37.50 ± 0.25 %, 4.36 ± 0.23 % and 9.14 ± 0.75 % in roasted kernels.

The Student t test shows that the roasting influences significantly ($P < 0.05$) all the biochemical composition of kernels.

Table 1. Biochemical composition of *C. lanatus* dried kernels and roasted kernels

Components (%)	*C. lanatus* kernels		Statistics	
	KD	KR	*t*	*P*
Dry matter	95.05 ± 0.39[b]	98.14 ± 0.20[a]	5.36	< 0.001
Moisture	4.95 ± 0.39[a]	1.86 ± 0.20[b]	5.36	< 0.001
Ashes	2.25 ± 0.03[b]	3.93 ± 0.13[a]	7.47	< 0.001
Protein (*N* x 6.25)	30.43 ± 0.28[b]	37.50 ± 0.25[a]	8.95	< 0.001
Lipids	54.20 ± 0.64[a]	40.12 ± 0.28[b]	9.24	< 0.001
Fiber	2.86 ± 0.31[b]	4.36 ± 0.23[a]	3.47	≈ 0.001
Carbohydrates	5.32 ± 1.14[b]	9.14 ± 0.75[a]	2.61	≈ 0.010
Gross energy (Kcal/100g)	630.78 ± 3.45[a]	569.31 ± 1.88[b]	8.26	< 0.001

Note. All determinations were carried out in triplicate and mean value ± standard deviation (SD) is reported. For each component, values with different superscript letters are significantly different ($P < 0.05$). KD, Kernels dried; KR, Kernels roasted.

4.2 Effect of Extraction Method on Chemical Indicators of C. Lanatus Kernels Oil

This part of the work concernes oils extracted by press and those extracted by solvent. The results showed that the acid values are 1.50 ± 0.39 and 2.22 ± 0.19 mgKOH/g in oils extracted by press against 4.06 ± 0.53 and 4.18 ± 0.25 mgKOH/g in oils extracted by solvent; and the peroxide values were 0.76 ± 0.01 and 1.99 ± 0.01 meq.O_2/kg in oils extracted by press against 6.70 ± 0.99 and 5.06 ± 0.66 meq.O_2/kg in oils extracted by solvent. Iodine values are 125.25 ± 3.31 and 116.75 ± 1.77 gI_2/100g in dried kernels oils against 114.88 ± 2.49 and 103.23 ± 1.32 gI_2/100g in roasted kernels oils (Table 2).

ANOVA shows that the extraction method influences significantly ($P < 0.001$) all chemical indices; while roasting influences significantly ($P < 0.001$) the iodine value.

Table 2. Chemical indices of *C. lanatus* dried kernels and roasted kernels oils extracted by mechanical and chemical methods

Chemical indices	*C. lanatus* kernels oils				Statistics	
	DKOP	DKOS	RKOP	RKOS	*F*	*P*
Acid value (mgKOH/g)	1.50 ± 0.39[b]	4.06 ± 0.53[a]	2.22 ± 0.19[b]	4.18 ± 0.25[a]	13.52	< 0.001
Peroxide value (meq.O_2/kg)	0.76 ± 0.01[b]	6.70 ± 0.99[a]	1.99 ± 0.01[b]	5.06 ± 0.66[a]	21.17	< 0.001
Iodine value (gI_2/100g)	125.25 ± 3.31[a]	116.75 ± 1.77[b]	114.88 ± 2.49[b]	103.23 ± 1.32[c]	14.93	< 0.001

Note. All determinations were carried out in triplicate and mean value ± standard deviation (SD) is reported. For each chemical index, values followed with same superscript letters do not differ significantly ($P < 0.05$). DKOP, dried kernels oil extracted by press; DKOS, dried kernels oil extracted by solvent; RKOP, roasted kernels oil extracted by press; RKOS roasted kernels oil extracted by solvent.

4.3 Roasting Effect on the Physicochemical Properties of C. Lanatus Kernels Oil

Dried kernels oil is pale yellow while roasted kernels oil is dark brown. They are liquid at 20 ℃. Viscosity and activation energy were respectively 53.78 ± 0.02 mPas and 4.17 ± 0.00 kJ/mol in dried kernels oil against respectively 50.06 ±0.02 mPas and 3.77 ± 0.00 kJ/mol in roasted kernels oil (Table 3). PH, acid, peroxide, iodine and saponification values, the phenols, unsaponifiables and carotenoids contents were respectively 5.23 ± 0.00, 1.00 ± 0.00 mgKOH/g, 0.59 ± 0.00 meq.O_2/kg, 124.58 ± 0.35 gI_2/100g, 199.56 ± 0.03 mgKOH/g, 7.00 ± 0.04 mg/100g, 0.81 ± 0.01 % and 100.64 ± 1.53 mg/100g in dried kernels oil against respectively 5.50 ± 0.01, 2.22 ± 0.01 mgKOH/g, 1.97 ± 0.03 meq.O_2/kg, 113.10 ± 0.20 gI_2/100g, 179.52 ± 0.04 mgKOH/g, 3.79 ± 0.15 mg/100g, 0.59 ± 0.01 % and 58.44 ± 2.00 mg/100g in roasted kernels oil (Table 4).

The Student t test shows that the physicochemical properties of both oils were significantly different ($P < 0.001$), with the exception of their specific gravity and their refraction index which are respectively approximately 0.9 and 1.47 (Table 3).

Table 3. Physical properties of *C. lanatus* dried kernels and roasted kernels oils

Physical properties	*C. lanatus* kernels oils		Statistics	
	DKO	RKO	*t*	*P*
State at 20 ℃	Liquid	Liquid	-	-
Colour	Pale yellow	Dark brown	-	-
Specific gravity at 25 ℃	0.92 ± 0.01^{a}	0.91 ± 0.00^{a}	1.00	0.374
Refractive index at 25 ℃	1.470 ± 0.00^{a}	1.471 ± 0.00^{a}	1.77	0.151
Viscosity at 40 ℃ (mPas)	53.78 ± 0.02^{a}	50.06 ± 0.02^{b}	137.37	< 0.001
Activation energy (kJ/mol)	4.17 ± 0.00^{a}	3.77 ± 0.00^{b}	-	-

Note. All determinations were carried out in triplicate and mean value ± standard deviation (SD) is reported. For each property, values with same superscript letters are not significantly different ($P < 0.05$). DKO, dried kernels oil; RKO, roasted kernels oil.

Table 4. Chemical properties of *C. lanatus* dried kernels and roasted kernels oils

Chemical properties	*C. lanatus* kernels oils		Statistics	
	DKO	RKO	*t*	*P*
PH at 25 ℃	5.23 ± 0.00^{b}	5.50 ± 0.01^{a}	18.11	< 0.001
Acid value (mgKOH/g)	1.00 ± 0.00^{b}	2.22 ± 0.01^{a}	175.72	< 0.001
Acidity (%)	0.50 ± 0.00^{b}	1.12 ± 0.00^{a}	175.72	< 0.001
Peroxide value (meqO_2/Kg)	0.59 ± 0.00^{b}	1.97 ± 0.03^{a}	51.35	< 0.001
Iodine value (gI_2/100g)	124.58 ± 0.35^{a}	113.10 ± 0.20^{b}	28.21	< 0.001
Saponification value (mgKOH/g)	199.56 ± 0.03^{a}	179.52 ± 0.04^{b}	377.23	< 0.001
Ester value (mgKOH/g)	198.55 ± 0.03^{a}	177.30 ± 0.05^{b}	364.65	< 0.001
Total phenols (mg/100g)	7.00 ± 0.04^{a}	3.79 ± 0.15^{b}	20.40	< 0.001
Insaponifiables (%)	0.81 ± 0.01^{a}	0.59 ± 0.01^{b}	15.37	< 0.001
Carotenoids (mg/100g)	100.64 ± 1.53^{a}	58.44 ± 2.00^{b}	16.72	< 0.001

Note. All determinations were carried out in triplicate and mean value ± standard deviation (SD) is reported. For each property, values with different superscript letters differ significantly ($P < 0.05$). DKO, dried kernels oil; RKO, roasted kernels oil.

The UV-visible spectrum consists of two superposed curves having each maximum absorbance at 220, 280 and 440 nm. The absorbance decreases rapidly between 280 and 400 nm, from 1.01 to 0.18 for dried kernels oil and from 1.06 to 0.21 for roasted kernels oil; but it varies slightly between 440 and 600 nm with a value close to 0.3 for the two oils (Figure 2).

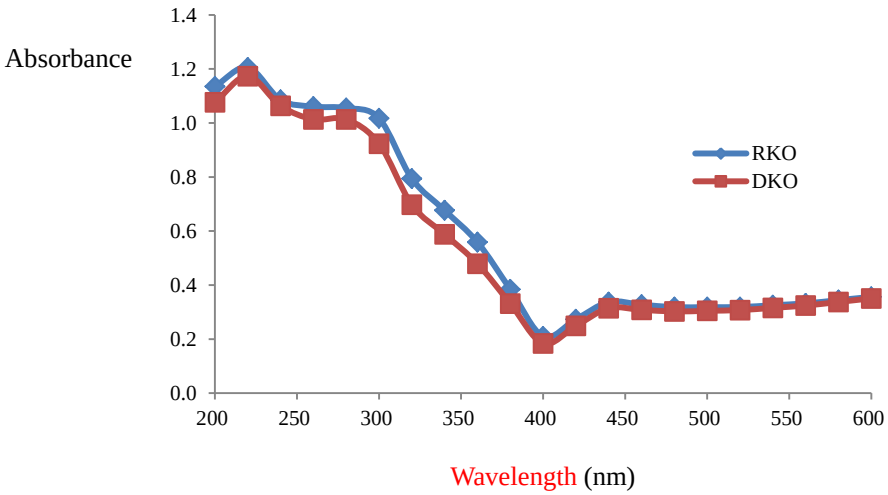

Figure 2. UV-visible spectra of *C. lanatus* dried kernels and roasted kernels oils

Note. UV-visible spectra were obtained by measuring absorbance, between 200 and 600 nm, of *C. lanatus* dried kernels and roasted kernels oils diluted to 1 % in hexane (Besbes et al., 2004). DKO, dried kernels oil; RKO, roasted kernels oil.

4.4 Roasting Effect on Antinutrients of C. Lanatus Kernels Oil

Oxalates, phytates and cyanogenic glycosides contents of two oils are shown in Table 5. The oxalates are represented by 53.57 ± 0.51 mg/100g in dried kernels oil and 55.74 ± 0.05 mg/100g in roasted kernels oil (about 0.05 % in the two oils). The two oils do not contain phytates and neither cyanogenic glycosides.

Table 5. Antinutritional factors of *C. lanatus* dried kernels and roasted kernels oils

Antinutrients (mg/100g)	*C. lanatus* kernels oils		Statistics	
	DKO	RKO	*t*	*P*
Oxalate	53.57 ± 0.51[b]	55.74 ± 0.05[a]	4.20	0.014
Phytate	0.00 ± 0.00[a]	0.00 ± 0.00[a]	-	-
Cyanogenic compounds	0.00 ± 0.00[a]	0.00 ± 0.00[a]	-	-

Note. Values are means ± standard deviation (SD) of triplicate determinations. For each antinutrient, values with different superscript letters are significantly different ($P < 0.05$). DKO, dried kernels oil; RKO, roasted kernels oil.

5. Discussion

The biochemical composition analysis showed a significant difference between dried kernels and roasted kernels of *C. lanatus*. This significant difference is due to the heat treatment (250 ℃ for 20 min) to which the kernels were subjected during roasting. On this point, Agarwal (2014) showed that the heat treatment of soybeans causes changes in their biochemical composition. Similar results were obtained by Jimoh, Fagbenro, and Adeparusi (2011) who studied the changes in the chemical composition during processing (raw, cooked and grilled) of sesame (*Sesamum indicum*) seeds meal. As for Yaacoub (2009), he showed that among the steps of the oilseeds and nuts processing method, the step of roasting is particularly critical in the formation of newly formed compounds. Given these results, it appears necessary to control the couple temperature/time during roasting to limit these biochemical changes and preserve the nutritional and cosmetic values of kernels.

Furthermore, we observed that both kernels (dried and roasted) are rich in lipid and protein. The abundance of lipids and proteins of dried kernels has already been demonstrated by Loukou et al. (2007) and Gbogouri et al. (2011) who also worked on the seeds of *C. lanatus* cultivated in Ivory Coast. Regarding the roasted kernels, these results could confirm that the roasting parameters (temperature: 250 ℃; time: 20 min) used in this study are appropriate to preserve the wealth of *C. lanatus* kernels in these two compounds. The protein content of the roasted kernels is higher than that of dried kernels. Similar results were obtained by Mariod et al. (2012) that determined the effects of roasting and boiling on the chemical composition of safflower seeds. This indicates that the roasted kernels are considerable sources of protein. The lipid content of the roasted kernels is lower than that of dried kernels obtained by Taiwo et al. (2008) and by Olaofe et al. (2012). However, the lipid content is higher than that of conventional oilseeds such as cotton (15.0 to 24.0 %), soy (17.0 to 21.0 %) and olive (20.0 - 25.0 %) (Pritchard, 1991). This means that the *C. lanatus* roasted kernels are also significant sources of lipids.

Proteins and lipids play many roles in the human and animal organism, and are important in human nutrition. Therefore, their presence in large quantities in the *C. lanatus* roasted kernels mean that these kernels are a good nutritional potential for food and feed.

The acid value is a chemical indicator that allows both the classification of the oils, and obtains information on their state of alteration by hydrolysis. As for the peroxide value, it allows to evaluate the early stages of oxidation of the oils. These two parameters are therefore important to assess the quality of oil.

From the results obtained, *C. lanatus* kernels oils extracted by press have low acid and peroxide values relative to those extracted by solvent. These results agree with those obtained by Haloui, Zekhnini, and Hatimi (2015) for argan oils. Oils extracted by press have thus better chemical quality compared with those extracted by solvent. Oils extracted by press are to be classified in the category "virgin oils and cold pressed oils" as their acid and peroxide values are respectively below 4.0 mgKOH/g and 15 meq.O_2/kg (Codex Alimentarius, 1999). The oils extracted by solvent have acceptable acid and peroxide values; however, after extraction, it should be refined to improve their quality. The high acid and peroxide values of oils extracted by solvent are probably due on the one hand, to the heating of the oil during the extraction (60 to 80 ℃ for 4 – 6 h) and the evaporation of the solvent (100 ℃ for 24 h), and on the other hand, in that the cucurbits oils are rich in polyunsaturated fatty acids which hydrolyze and oxidize rapidly under the effect of heat (Loukou et al., 2012).

Regarding the iodine value, it evaluates the degree of unsaturation of oil. In practice, its value classifies oils into four major categories: saturated (5 to 50 gI_2/100g), mono-unsaturated (50 to 100 gI_2/100g), di-unsaturated (100

to 150 gI_2/100g) and tri-unsaturated (> 150 gI_2/100g) oils (CIRAD, 2008).

According to the results, roasting and solvent extraction have decreased iodine values of oils. This can be explained by the fact that heat treatments, employees at these two methods, have led to changes in the biochemical composition (Agarwal, 2014). However, all studied oils are classified in the category "di-unsaturated oils" as their iodine values are between 100 and 150 gI_2/100g. Previous work by Olaofe et al. (2012) and Gbogouri et al. (2013) revealed that *C. lanatus* kernels oil contains linoleic acid over 60 % (di-unsaturated fatty acid). That would justify the results obtained in this study. Thus, despite the variation of the observed iodine values, the structure of the oil seems not to have changed significantly.

The specific gravities of *C. lanatus* kernels oils are similar to that reported for most conventional oilseeds (Codex Alimentarius, 1999) which are 0.9. Additionally, their viscosities are in the range (50 to 100 mPas) of most vegetable oils (Besbes et al., 2004). These results confirm their liquid state at room temperature and this physical characteristic is suitable for the preparation of skin care products (Dhellot et al., 2006). Low peroxide values obtained in this study indicate that *C. lanatus* kernels oils are less susceptible to oxidative rancidity at room temperature (DeMan, 1992). Therefore, these oils are suitable, in combination with antioxidants, for cosmetic formulations (Judde, 2004). Their high saponification values make it recommendable for manufacturing soap, creams and shaving foam (Wolf, 1968). Furthermore, their unsaponifiable contents are higher than those reported for other cosmetic oils such as cottonseed (0. 52%), peanut (0.33 %) and palm kernels (0.22 %) oils (Kapseu & Parmentier, 1997). This lipid fraction is a good source of stabilizers and provides essential moisture to the skin (Helme, 1990). The decrease in their absorbance, in the range of 290 to 400 nm, would be advantageous for use in the formulation of cosmetic products that offer protection against UV rays (Besbes et al., 2004).

The refractive indices of the *C. lanatus* kernels oils are in the range of those reported for edible oils (Rossell, 1991). These oils have low free fatty acids contents; then they would be advisable for seasoning salads (Matos et al., 2009) and could be kept for a longer period (Anwar, Chata, & Hussain, 2007). Their iodine values are higher than oils rich in saturated fatty acids such as coconut (6.3 to 10.6 gI_2/100g), palm (50 to 55 gI_2/100g), palm kernels (14.1 to 21 gI_2/100g) oils; but they are similar to those oils rich in polyunsaturated fatty acids such as cottonseed (100 to 123 gI_2/100g), sesame (104 to 120 gI_2/100g) and sunflower (118 to 141 gI_2/100g) oils (Codex Alimentarius, 1999). Given their iodine values, the *C. lanatus* kernels oils are semi-drying and rich in di-unsaturated fatty acids (linoleic acid). Therefore, they would be nutritionally beneficial for patients with lipid disorders (Njoku, Muma, Ononogbu, & Eleanya, 2001).

The oxalates contents of *C. lanatus* kernels oils are significantly lower than those of groundnut (0.42 %) and palm (0.49 %) oils (Inuwa et al., 2011). In addition, these oils do not contain phytates and neither cyanogenic glycoside. These results confer on them better suitability for food use.

6. Conclusion

This study showed that roasting influences the physicochemical characteristics of *C. lanatus* kernels and their oil, and oil extracted by cold pressing is better chemical quality. It found that *C. lanatus* roasted kernels are also sources of lipid and protein for human being and animal food, and roasted kernels oil are rich in di-unsaturated fatty acids; which would give him nutritional and cosmetic properties. Moreover, the saponification value and the physical properties of this oil make it suitable for cosmetic industry of skin care products. Its low acid and peroxide values, the virtual absence of anti-nutrients make it safe for human use. Given all these potentialities, *C. lanatus* roasted kernels oil could be used in food and cosmetic industries. This study could be improved by optimization of the roasting process of *C. lanatus* kernels, and the study of the effects of roasting on the minor compounds and oxidative stability of oils.

Acknowledgements

The authors are gratefully to the DGCD (Direction Générale de la Coopération au Développement, Brussels, Belgium) for their financial support.

References

Afane, E., Lando, G., Biyiti, L., Ossima, G. A., & Atchou, G. (1997). Boiling palm oil vapours, a broncho-annoying acid. *Médecine d'Afrique noire, 44*, 604-607.

Agarwal, K. (2014). Comparative Biochemical Analysis of Raw and Processed Soybean. *IIS University Journal Science and Technology, 3*(1), 61-66. Retrieved from http://iisjost.org/sites/default/files/iisjost/2014/PDF/9.%20Kalpana%20Agarwal.pdf

Agence Française de Normalisation – AFNOR. (1986). *The French standards collection, fats, oleaginous seeds and by-products*, 4th edn. Paris: AFNOR.

Anjum, F., Anwar, F., Jamil, A., & Iqbal, M. (2006). Microwave Roasting Effects on the Physico-chemical Composition and Oxidative Stability of Sunflower Seed Oil. *Journal of the American Oil Chemists' Society, 83*(9), 777-784. http://dx.doi.org/10.1007/s11746-006-5014-1

Anwar, F., Chata, S. A. S., & Hussain, A. I. (2007). Assessment of oxidative deterioration of soybean oil at ambient and sunlight storage. *Grasas y Acietes, 58*(4), 390-395. Retrieved from http://grasasyaceites.revistas.csic.es/index.php/grasasyaceites/article/download/451/426http%3A

Association of Official Analytical Chemists – AOAC (1990). *Official Methods of Analysis*. 15th edn. Washington, DC: AOAC.

Association of Official Analytical Chemists – AOAC (1997). *Official Methods of Analysis*. 15th edn. Washington, DC: AOAC.

Atwater, W. O., & Benedict, F. G. (1902). Experiments on the metabolism of matter and energy in human body, 1898-1900, United States. *Office of experiment stations*. Bulletin N°109. Government Printing Office, Washington, D.C. https://doi.org/10.5962/bhl.title.123031

Besbes, S., Blecker, C., Deroanne, C., Lognay, G., Drira, N.-E., & Attia, H. (2004). Quality Characteristics and Oxidative Stability of Date Seed Oil. *Food Science and Technology International, 10*(5), 333-338. https://doi.org/10.1177/1082013204047777

Centre de coopération internationale en recherche agronomique pour le développement – CIRAD (2008). *Guide technique pour une utilisation énergétique des huiles végétales*. Brasília: CIRAD.

Codex Alimentarius (1999). *Codex Alimentarius Standards for Fats and Oils from Vegetable Sources*. Section2. Codex Alimentarius Standards for Named Vegetable oils. Codex Alimentarius – Stan 210.

DeMan, J. M. (2000). Chemical and physical properties of fatty acids. In: C. K. Chow (2nd Ed.), *Fatty acids in foods and their health implications* (pp. 17-46). New York.

Dhellot, J. R., Matouba, E., Maloumbi, M. G., Nzikou, J. M., Ngoma, D. G., Linder, M., ... Parmentier, M. (2006). Extraction, chemical composition and nutritional characterization of vegetable oils: case of *Amaranthus hybridus* (var 1 and 2) of Congo Brazzaville. *African Journal of Biotechnology, 5*, 1095-1101. Retrieved from http://www.ajol.info/index.php/ajb/article/download/42979/26539

Ferchau, E. (2000). Equipment for decentralised cold pressing of oil seeds. Retrieved from http://www.folkecenter.net/mediafiles/folkecenter/pdf/dk/efdcpos_ef.pdf

Gbogouri, G. A., Brou, K., Linder, M., Tehrany, E. A., Gnakri, D., & Zoro Bi, I. A. (2011). Comparative study of physicochemical and thermal properties of the seed oils of three cucurbit species. *International Journal of Biological and Chemical Sciences, 5*(3), 1165-1177. http://dx.doi.org/10.4314/ijbcs.v5i3.72246

Gbogouri, G. A., Brou, K., Beugre, G. A. M., Gnakri, D., & Linder, M. (2013). Assessment of the thermo-oxidation of three cucurbit Seed oils by differential scanning calorimetry. *Innovative Romanian Food Biotechnology, 12*, 32-39. Retrieved from http://www.bioaliment.ugal.ro/revista/12/Paper%2012.3.pdf

Haloui, B. R., Zekhnini, A., & Hatimi, A. (2015). Effects of extraction methods on chemical composition and oxidative stability of Argan oil. *Journal of Chemical and Pharmaceutical Research, 7*(6), 518-524. Retrieved from http://s3.amazonaws.com/academia.edu.documents/38096309/JCPR-extractionsargan.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1485474855&Signature=MdQyJ5uMXEAWIZVNUg5kvJ2xlP8%3D&response-content-disposition=inline%3B%20filename%3DEffects_of_extraction_methods_on_chemica.pdf

Harhar, H., Gharby, S., Kartah, B., El Monfalouti, H., Guillaume, D., & Charrouf, Z. (2011). Influence of argan kernel roasting-time on virgin argan oil composition and oxidative stability. *Plant Foods for Human Nutrition, 66*(2), 163-168. http://dx.doi.org/10.1007/s11130-011-0220-x

Helme, J. P. (1990). Lipids and Cosmetology. *Revue Francaise des Corps Gras*, 11, 6-36.

Inuwa, H. M., Aina, V. O., Gabi, B., Aimola, I., & Toyin, A. (2011). Comparative determination of antinutritional factors in groundnut oil and palm oil. *Advance Journal of Food Science and Technology, 3*, 275-279.

International Union of Pure and Applied Chemistry – IUPAC (1979). *Standard methods for the analysis of oils,*

fats and derivatives, 6th edn. Pergamon, Oxford: IUPAC.

Jimoh, W. A., Fagbenro, O. A., & Adeparusi, E. O. (2011). Effect of processing on some minerals, anti-nutrients and nutritional composition of sesame (*sesamum indicum*) seed meals. *Electronic journal of environmental, agricultural and food chemistry, 10*(1), 1858-1864.

Judde, A. (2004). Prevention of the fatty acids oxidation in a cosmetic product: mechanisms, consequences, determination methods, what antioxydants for what applications? *Oléagineux, Corps Gras, Lipides, 11*, 414-418. https://doi.org/10.1051/ocl.2004.0414

Kapseu, C., & Parmentier, M. (1997). Fatty acid composition of some vegetable oils from Cameroon. *Sciences des Aliments, 17*, 325-331.

Liauw, M. Y., Natan, F. A., Widiyanti, P., Ikasari, D., Indraswati, N., & Soetaredjo, F. E. (2008). Extraction of neem oil (*Azadirachta indica* A. Juss) using n-hexane and ethanol: studies of oil quality, kinetic and thermodynamic. *ARPN Journal of Engineering and Applied Sciences, 3*(3), 49-54. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.613.7721&rep=rep1&type=pdf

Loukou, A. L., Gnakri, D., Djè, Y., Kippré, A. V., Malice, M., Baudoin, J.-P., & Zoro Bi, I. A. (2007). Macronutrient composition of three cucurbit species cultivated for seed consumption in Côte d'Ivoire. *African Journal of Biotechnology, 6*(5), 529-533. Retrieved from http://www.academicjournals.org/journal/AJB/article-full-text-pdf/37AE3B46207

Loukou, A. L., Lognay, G., Baudoin, J.-P., Kouame, L. P., & Zoro Bi, I. A. (2013). Effects of fruit maturity on oxidative stability of *lagenaria siceraria* (Molina) standl. Seed oil extracted with hexane. *Journal of Food Biochemistry, 37*(4), 475-484. http://dx.doi.org/10.1111/j.1745-4514.2012.00657.x

Mariod, A. A., Ahmed, Y. S., Abdelwahab, I. S., Cheng, F. S., Eltom, M. A., Yagoub, O. S., & Gouk, W. S. (2012). Effects of roasting and boiling on the chemical composition, amino acids and oil stability of safflower seeds. *International Journal of Food Science & Technology, 47*(8), 1737-1744. http://dx.doi.org/10.1111/j.1365-2621.2012.03028.x

Matos, L., Nzikou, J. M., Matouba, E., Pandzou-Yembe, V. N., Mapepoulou, T. G., Linder, M., & Desobry, S. (2009). Studies of *Irvingia gabonensis* seed kernels: oil technological applications. *Pakistan Journal of Nutrition, 8*(2), 151-157. http://dx.doi.org/10.3923/pjn.2009.151.157

McDaniel, A. K., White, L. B., Dean, L. L., Sanders, H. T., & Davis, P. J. (2012). Compositional and Mechanical Properties of Peanuts Roasted to Equivalent Colors using Different Time/Temperature Combinations. *Journal of Food Science, 77*(12), C1293-C1299. http://dx.doi.org/10.1111/j.1750-3841.2012.02979.x

Moss, J. R., & Otten, L. (1989). A Relationship Between Color Development and Moisture Content During Roasting of Peanut. *Canadian Institute of Food Science and Technology, 22*(1), 34-39. http://dx.doi.org/10.1016/S0315-5463(89)70298-4

Nitiéma-Yefanova, S., Son, G., Yé, S., Nébié, C. H. R., & Bonzi-Coulibaly, Y. (2012). Optimisation des paramètres d'extraction à froid de l'huile d'*Azadirachta indica* A. Juss et effets sur quelques caractéristiques chimiques de l'huile extraite. *Biotechnologie, Agronomie, Société et Environnement, 16*(4), 423-428. Retrieved from http://www.pressesagro.be/ojs/index.php/base/article/download/625/612

Njoku, O. U., Muma, A. F., Ononogbu, I. C., & Eleanya, R. (2001). Preliminary investigation on some nutritional and toxicological properties of *Ricinodendron heudelotti* seed oil. *Nigerian journal of biochemistry and molecular biology, 16*, 132-133.

Nzikou, J. M., Matos, L., Bouanga-Kalou, G., Ndangui, C. B., Pambou-Tobi, N. P. G., Kimbonguila, ... Desobry, S. (2009). Chemical Composition on the Seeds and Oil of Sesame (*Sesamum indicum* L.) Grown in Congo-Brazzaville. *Advance Journal of Food Science and Technology, 1*, 6-11.

Onwuka, G. (2005). Antinutrional factors. In: Naphohla Prints (Ed.), *Food analysis and instrumentation* (pp. 133-161). Nigeria.

Olaofe, O., Ogungbenle, H. N., Akhadelor, B. E., Idris, A. O., Omojola, O. V., Omotehinse, O. T., & Ogunbodede, O. A. (2012). Physicochemical and fatty acids composition of oils from some legume seeds. *International Journal of Biology, Pharmacy and Allied Sciences, 1*(3), 355-363. Retrieved from http://ijbpas.com/pdf/1336902078MS%20IJBPAS%202012%201033.pdf

Pritchard, J. L. R. (1991). Analysis and properties of oilseeds. In: J. B. Rossell, & J. L. R. Pritchard (Eds.), *Analysis of oilseeds, fats and fatty foods* (pp. 39-102). New York: Elsevier Applied Sciences.

Rossell, J. B. (1991). Vegetable oils and fats. In: J. B. Rossell (Ed.), *Analysis of oilseeds, fats and fatty foods* (pp. 261-325). London.

Schippers, R. R. (2000). *African indigenous vegetables: An overview of the cultivated Species*. Natural Resources Institute/ACP-EU Technical centre for Agricultural and Rural Cooperation, Chatham.

Shimoda, M., Nakada, Y., Nakashima, M., & Osijima, Y. (1997). Quantitative comparison of volatile flavour compounds in deep-roasted and light-roasted sesame seed oil. *Journal of Agricultural and Food Chemistry, 45*(8), 3193-3196. http://dx.doi.org/10.1021/jf970172o

Sultana, R., Saleem, R., & Ambrat (2011). Effect of Roasting Temperature on the Fatty Acid Composition and Physicochemical Characteristics of Extracted Oil *Carthamus tinctorius* Thori-78 of Pakistani Origin Seeds. *Pakistan Journal of Scientific and Industrial Research Series A: Physical Sciences*, 54(1), 26-32. Retrieved from http://www.pjsir.org/documents/journals/54(1)-complete.pdf#page=37

Taiwo, A. A., Agbotoba, M. O., Oyedepo, J. A., Shobo, O. A., Oluwadare, I., & Olawunmi, M. O. (2008). Effects of drying methods on properties of water melon (*Citrullus lanatus*) seed oil. *African Journal of Food, Agriculture, Nutrition and Development, 8*(4), 492-501. Retrieved from https://www.ajfand.net/Volume8/No4/Taiwo3075.pdf

Torlak, E., Sert, D., & Serin, P. (2013). Fate of Salmonella during sesame seeds roasting and storage of tahini. *International Journal of Food Microbiology, 163*(2-3), 214-217. http://dx.doi.org/10.1016/j.ijfoodmicro.2013.03.010

Vermaak, I., Kamatou, G. P. P., Komane-Mofokeng, B., Viljoen, A. M., & Beckett, K. (2011). African seed oils of commercial importance – Cosmetic applications. *South African Journal of Botany, 77*(4), 920-933. http://dx.doi.org/10.1016/j.sajb.2011.07.003

Wolf, J. P. (1968). *Fatty substances analysis manual* (1st ed.). Paris: Azoulay.

Yaacoub, R. (2009). *Nutritional and sanitary impact of nuts and seeds roasting: the interest of using fluorescence spectroscopy as a tool to control neoformed compounds* (Doctoral dissertation, AgroParisTech, Paris, France). Retrieved from https://pastel.archives-ouvertes.fr/pastel-00005932

Zoro Bi, I. A., Koffi, K. K., & Djè, Y. (2003). Caractérisation botanique et agronomique de trois espèces de cucurbites consommées en sauce en Afrique de l'Ouest: *Citrullus* sp., *Cucumeropsis mannii* Naudin et *Lagenaria siceraria* (Molina) Standl. *Biotechnologie, Agronomie, Société et Environnement*, 7(3–4), 189-199. Retrieved from http://www.bsa.ulg.ac.be/ojs/index.php/base/article/download/206/196

Zoro Bi, I. A., Koffi, K. K., Djè, Y., Malice, M., & Baudoin, J.-P. (2006). Indigenous Cucurbits of Côte d'Ivoire: a Review of their Genetic Resources. *Sciences & Nature, 3*(1), 1-9. Retrieved from https://orbi.ulg.ac.be/bitstream/2268/34207/1/ZoroBietal2006_SN.pdf

Zoué, T. L., Bédikou, E. M., Gonnety, T. J., Faulet, M. B., & Niamké, L. S. (2012). Two Novel Non-Conventional Seed Oil Extracts with Antioxidant and Antimicrobial Activities. *Tropical Journal of Pharmaceutical Research, 13*(3), 469-475. http://dx.doi.org/10.4314/tjpr.v11i3.17