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Comparative study of physicochemical and thermal properties of the seed oils of three cucurbit species

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ABSTRACT

Three indigenous cucurbit seeds from Ivory Coast namely *Cucumeropsis mannii* Naudin, *Citrullus lanatus* var. Citroides (Thrumb.) Matsum & Nakai and *Cucumis melo* var. Agrestis were investigated for the physicochemical properties. Thermal properties of their crude oils extracted by a cold solvent method were also tested. Physicochemical characterization of the seeds showed that they are important sources of proteins, lipids, carbohydrates and mineral elements. *C. lanatus* seeds had the highest lipid content (46.40%) followed by *C. melo* seeds (36.50%) and *C. mannii* seeds (35.70%) on dry weigh bases. Most of the index values and chemical characteristics of extracted seed oils are not significantly different, except for the peroxide value and the color parameters of *C. mannii*. Linoleic acid, whose values ranged from 54.84% to 70.76%, was the major fatty acid out of all seed oil species. The thermal properties revealed that *C. melo* seed oil had low transition temperatures followed by *C. lanatus* seed oil and *C. mannii* seed oil depending on their fatty acid compositions. These results suggest that these thermal properties could be used in the industrial fractionation and the cucurbit seed oils may be used as edible oils due to their similarity to the commonly used edible oils.
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Keywords: Cucurbit seed oil, physicochemical properties, differential scanning calorimetry, fatty acid.

INTRODUCTION

Cucurbits species are a prized food for their oleaginous seeds. Their kernels are consumed as thickener soup called *pistachio* soup in Ivory Coast, *egussi* soup in Nigeria. In Ivory Coast, certain species of cucurbit are cultivated in small scales for their oily seeds. *Citrullus lanatus*, *Cucumeropsis mannii* and *Cucumeropsis melo* are most abundant

compared to *Cucurbita pepo* and *Lagenaria siceraria* (Zoro Bi et al., 2006).

Zoro Bi et al. (2006) reported a review of the inter- and intraspecies diversity of cucurbit species consumed in sauce in Ivory Cost: *C. melo* is locally called *lomi n'gatê*. Its seeds are toasted, ground and used as sauce thickener. The flesh of their fruits is light green and has bitter taste. *C. lanatus* locally

called *wlêwlê*, is the most common edible cucurbit cultivated in Ivory Coast. Their fruits are round or oval, uniformly light green or mottled light. *C. mannii* locally called *n'viêlê,* is a monocious annual climbing vine. Their fruits are uniformly light green or yellowish and blocky.

Some reports available on the composition of seeds and seed kernels of cucurbits indicated that they are rich in macronutrients: lipids, proteins and carbohydrates (Badifou, 1991a, 1991b; De Mello et al., 2000; Badifou, 2001; Loukou et al., 2007). The content of macronutrients varies between 20% and 50% depending on the species and the geographical regions. Teotia and Ramakrishna (1984) reported that the seeds of melon grown in India contained from 40 to 47% of oils and from 23 to 36% of proteins. Rashwan et al. (1993) showed that lipid and protein contents (on dry weight basis) for seed kernels of sweet melon varieties of *C. melo* were approximately 37% and 54%, respectively. In short, many studies on cucurbit varieties reported that they are an important oil source for human diet, a source of energy and carbon building blocks.

In Ivory Coast, the major source of commercial edible oil is palm. That is undoubtedly due to the failure to recognize the characteristics and sources of vegetable oil. However, studies of the properties of other vegetable oils on the laboratory scale could allow them to be used as edible. As seen above, cucurbit seeds were an important source of oil.

The purpose of this investigation is to obtain information about the chemical, the fatty acid composition and thermal characteristics of oils extracted from three species of cucurbit seeds (*C. lanatus*, *C. mannii* and *C. melo*) in order to determine their suitability as edible oil.

MATERIALS AND METHODS
Source of seeds and sample preparation

Sun-dried cucurbit seeds of *C. mannii* Naudin, *C. lanatus* var. *Citroides* (Thrumb.) Matsum & Nakai. and *C. melo* var. Agrestis

(Photographs 1)*,* were obtained from the Laboratory of genetic of University of Abobo-Adjamé (Ivory Coast). Seeds were crushed in a coffee grinder and stored in hermetic bags at - 20 °C until analysis.

Morphological characteristics of seeds were examined for weight and size (n =100) (estimated as length and width).

Proximate composition analyses

Crude protein was analyzed using the Kjeldahl Method (AOAC, 1997) with nitrogen analyzer (Gerhadt Vapodest, 50, Germany). Dry matter was determined gravimetrically after drying sample overnight at 105 °C. Lipid content was determined using the method of Folch et al. (1957). Ash was quantified after incinerating the sample in the muffle furnace at 550 °C overnight and minerals (potassium, sodium, calcium, magnesium) were analyzed by atomic absorption spectrophotometry (Perkin Elmer, Model 1100, Paris, France) following the method used by Idouraine et al. (1995). Carbohydrates content was determined through the method used by Samant and Rege (1989).

Energetic density (ED) was calculated with 4 kcal/g for carbohydrates, 4 kcal/g for proteins and 9 kcal/g for lipids according to Atwater and Benedict (1902).

Equation 1: ED = [(Protein content × 4) + (Lipid content × 9) + (Carbohydrate content × 4)] × Dry matter content / 100.

Lipid index was analyzed using standard procedures: peroxide value (Standard 965.33) of the AOCS (1997), acid value and free fatty acids (Norme Européenne, NF EN ISO 660, 1999), iodine value (Norme Européenne, NF EN ISO 3961, 1999) and unsaponifiable matter (Norme Internationale, ISO 18609, 2000).

The CIE L* a* b* coordinates of oils were directly read with a chromameter (Minolta) calibrated with white tile according to the method used by Besbes et al. (2004). In the color coordinate system, the L* is a measure of lightness and varies from +100 (white) to 0 (black), a* varies from +100 (red) to -100 (green) and b* varies from +100

(yellow) to -100 (blue).

The chroma value and hue angle value of oils were calculated as $(a*^2 + b*^2)^{1/2}$ and [tan-1(b*/a*)], respectively.

Bulk density of seed oils was determined using a 25 mL measuring cylinder at 22 °C. The sample was filled to a 25 mL cylinder, the weight to volume ratio was determined, and bulk density value reported as gram per millilitre. Specific gravity was calculated as the density of seed oil divided by density of water at 22 °C.

Gas chromatography analyses

Fatty acid methyl esters (FAME) were obtained by transmethylation of lipid aliquots (100 mg). According to Ackman (1998), samples were dissolved with 1.5 mL of hexane and 1.5 mL of borontrifluoride in methanol (8%, w/v), and heated at 100 °C under nitrogen for 1 h. After cooling, the fatty acid methyl esters were extracted in hexane under nitrogen.

FAME were analyzed by gas chromatography on Perichrom™ 2000 system (Saulx-les-Chartreux, France), equipped with a flame ionisation detector (FID) and fused silica capillary column (50 m × 0.25 mm × 0.5 µm, BPX70 SGE Australia Pty Ltd). Temperatures were set as follows: 2 min initial period at 120 °C, increasing at 40 °C/min to the second step at 180 °C for 8 min, and flowing out at 3 °C/min to the final period at 220 °C for 45 min. Injection and detector ports were maintained at 230 °C and 260 °C, respectively. Fatty acids were identified by comparing their relative retention time with appropriate vegetable standards and marine PUFA 2 standards from Supelco (Supelco Park, Bellefonte, PA 16823-0048 USA). The results, made in triplicate, were displayed as percent of total identified fatty acids.

Differential Scanning Calorimetry analysis

Thermal characteristics of oils were measured using Differential Scanning Calorimeter (DSC 204 F1 Phoenix®, Netzsch - Gerätebau GmbH, Germany). Purified nitrogen (99.9%) was the purge gas and flowed at 20 mL/min. The calorimeter was calibrated according to the standard procedures established by the manufacturer user book using indium and water. Approximately, 8-10 mg of sample were weighed into aluminium pans and covers were hermetically sealed into place while an empty hermetically sealed aluminium was used as reference. The sample and the reference pans were then placed inside the calorimeter and subjected to the following temperature program: heating to 50 °C and holding for 5 min. Cooling to -50 °C at the rate of 5 °C/min and holding for 5 min. Heating from -50 °C to 50 °C at 5 °C/min. The transition temperatures, enthalpies of fusion or of crystallization (J/g) were calculated using the Proteus® Software for thermal analysis (DSC 204 F1 Phoenix® Netzsch - Gerätebau GmbH, Germany).

Statistical analysis

Results are expressed as the mean ± standard deviation of several sample with Kyplot (version 2.0 beta 15, ©1997-2001, Koichi Yoshioka) statistical software. The data were statistically analyzed by one way analysis of variance (ANOVA). Means were compared by Turkey's test. Differences were considered statistically significant at $P < 0.05$.

RESULTS
Physicochemical characteristics of cucurbit seeds

The physicochemical characteristics of cucurbit seeds are shown in Table 1. The morphological aspect exhibited significant differences (P<0.05) between seeds for weight and size. *C. melo* seeds size is small, up to 0.55 cm (length) and weigh around 12 mg. *C. lanatus* seeds are yellowish and weigh around 45 mg. The seeds of *C. mannii* are large compared to those of the other two species. Their weight is around 184 mg and their length is around 1.95 cm.

There were significant differences (P<0.05) among the seeds species in their content of total crude protein, total crude lipid, total carbohydrates and ash (Table 1). The

protein content was 28.6%, 35.6% and 37.3% of dry matter for *C. lanatus*, *C. mannii* and *C. melo,* respectively. The carbohydrate content of the three species varied from 22% to 25%.

The cucurbit species analyzed in this work contain total lipids ranging from 35% to 46% of dry matter. *C. lanatus* seeds have the highest fat content (46%) compared to *C. mannii* seeds (35.7%) and *C. melo* seeds (36.5%).

There were great variations in the mineral content of the seed samples (Table 2). The potassium content, 806.1 mg/100 g for *C. mannii* and 500 mg/100 g for *C. lanatus,* was much higher than sodium, calcium and magnesium content in the three species. Calcium was the most abundant mineral element in *C. melo* seeds with the content up to 1426 mg/100g, around 14 times the level found for *C. mannii* seed oil (102 mg/100g) and around 31 times the level found for *C. lanatus*. Sodium content was low in the three sample seeds. It reached 28 mg/100 g for *C. melo*, 11 mg/100g for *C. mannii* and 43 mg/100g for *C. lanatus.*

Physicochemical properties of oils

Physicochemical properties of seed oils are shown in Table 3. The peroxide value of 9.78 meq O_2/kg of oil for *C. mannii* is significantly higher than 1.10 meq O_2/kg of oil for *C. lanatus* and than 2.72 meq O_2/kg of oil for *C. melo.* There is no significant difference (P>0.05) in the iodine value of the three species of cucurbit seeds : 115.5 g of I_2/100 g of oil for *C. melo*, 111.8 g of I_2/100 g of oil for *C. mannii* and 113 g of I_2/100 g of oil for *C. lanatus.*

The level of total free fatty acids of *C. melo* and *C. mannii* (1.13%) were ca. two times lower than the values of *C. lanatus* (2.15%) (Table 3). Oils extracted from cucurbit seeds were fluid at room temperature 25 ± 2 °C, and had an odor and color depending on the species. The *C. melo* seed oil was pale yellow, *C. lanatus* seed oil was yellow orange and *C. mannii* seed oil was green-yellow. Color data analysis showed a significant difference (P<0.05) in the color parameters of seed oils. The colour intensity (Chroma value) of *C. melo* and *C. mannii* seed oils (0.08; 0.09 respectively) was higher

than *C. lanatus* seed oil (0.06).

The bulk density and the specific gravity of oils were not significantly different (P>0.05) and ranged from 0.94 to 0.95 and from 0.95 to 0.96, respectively. The unsaponifiable matters content which is up to 0.5%, was identical for the three oils.

Fatty acids composition

The main fatty acid compositions of cucurbit seed oils are shown in Table 4. The fatty acid composition of investigated species contained essentially four fatty acids with no significant difference (P>0.05). Linoleic acid (C18:2n 6) was largely predominant, 70.76% for *C. melo*, 63.94% for *C. lanatus* and 54.84% for *C. mannii*. Palmitic acid (C16:0) and stearic acid (C18:0) contents were comparable in each species. Their contents were high in *C. mannii* and reached 16.33% for palmitic acid and 13.89% for stearic acid. The oleic acid content was 9.12%, 14,54% and 14.43% for *C. melo*, *C. mannii* and *C. lanatus,* respectively. Linolenic acid (C18:3n 3) was present in lower amount (0.42 - 0.46 %) in the investigated species. The total polyunsaturated fatty acids for *C. melo* (71.22%) were higher than total polyunsaturated fatty acids for *C. lanatus* (64.54%) and for *C. mannii* (55.23%). The amount of unsaturated n-6 was very high in the three oils, therefore the TUFA/TSFA ratio ranged from 2.30 to 4.10% of investigated oils.

Thermal properties

Thermal properties were performed using DSC to assess physical properties of seed oils. Figures 1 and 2 showed the DSC melting and cooling curves for the three cucurbits seed oils. All DSC data are summarized in Tables 5 and 6. The melting curves of oils showed three to four endothermic peaks ranging from -48.5 °C to 1.3 °C for *C. melo*, -39.5 °C to 13.8 °C for *C. mannii* and -47.7 °C to 6.0 °C for *C. lanatus.* The melting curves showed four peaks for *C. melo* (three peaks and two shoulders), four peaks for *C. lanatus* (two peaks and two shoulders), three peaks for *C. mannii* (two peaks and one shoulder) (Figure 1). The *C. melo* seed oil melting curve showed the lowest

onset and offset temperatures (-48.7 °C and 1.4 °C, respectively), followed by *C. lanatus* seed oil (-47.7 °C and 6 °C respectively). The *C. mannii* seed oil melting curve showed the highest onset and offset temperatures (-39.5 °C and 13.8 °C, respectively) (Table 6).

The cooling curves (Figure 2) showed two exothermic peaks at -13.0 °C and -36.5 °C for *C. melo*, at -3.5 °C and -35.5 °C for *C. mannii* and at -10 °C and -39.5 °C for *C. lanatus*. The onset temperature of crystallization (Table 6) was higher for *C. mannii* oil (1.3 °C) than the *C. lanatus* oil (-4.4 °C) and the *C. mannii* oil (-7.2 °C).

The melting enthalpy (Table 6) of *C. lanatus* oil was high (56.0 J/g), followed by *C. mannii* oil (47.8 J/g) and by *C. melo* oil (39.0 J/g). The crystallization enthalpies of oils were between -24.0 °C and -33.0 °C (Table 6).
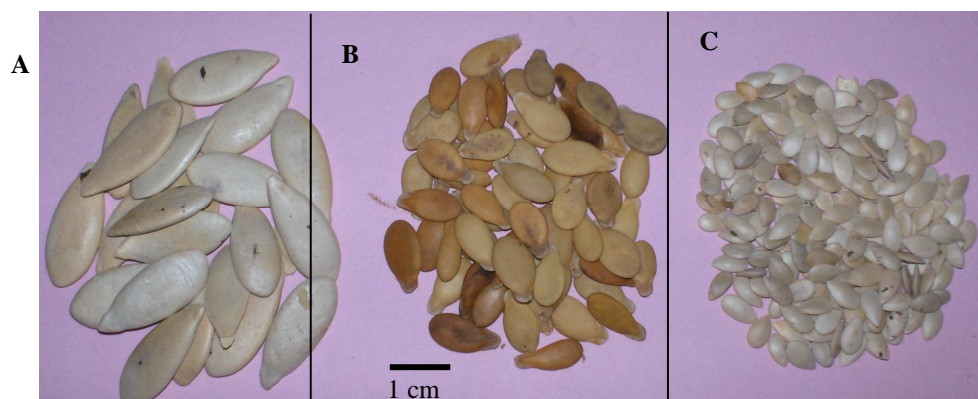
Photographs 1: Seeds of cucurbit species. A: *C. mannii* Naudin; B: *C. lanatus* var. Citroides (Thrumb.) Matsum & Nakai.; C: *C. melo* var. Agrestis L.
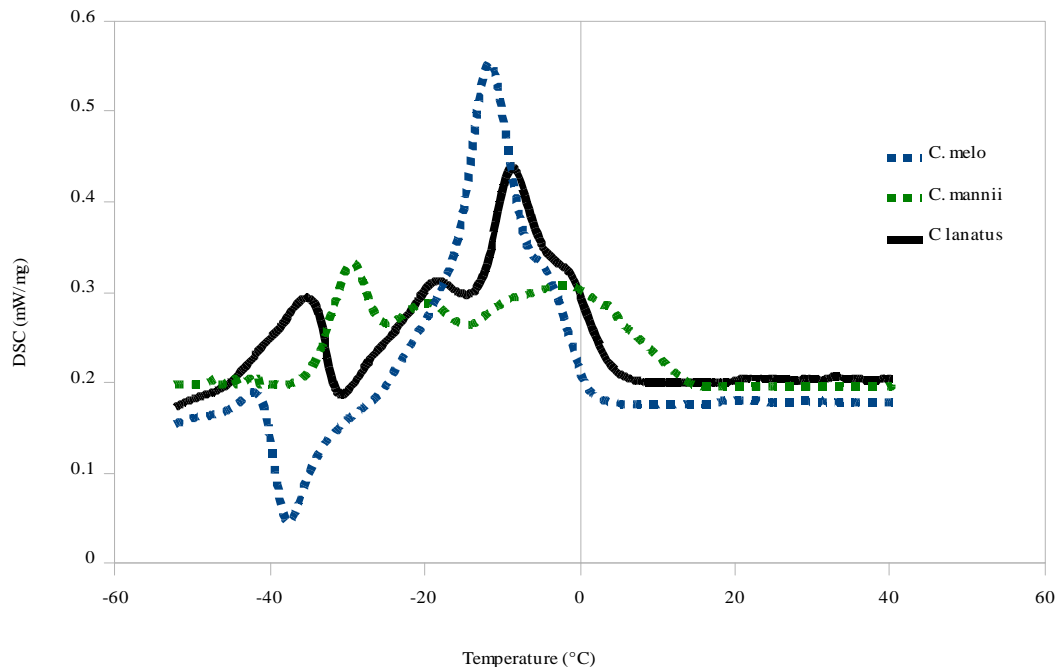
Figure 1: DSC melting curves of cucurbit seed oils at heating rate of 5 °C/min.
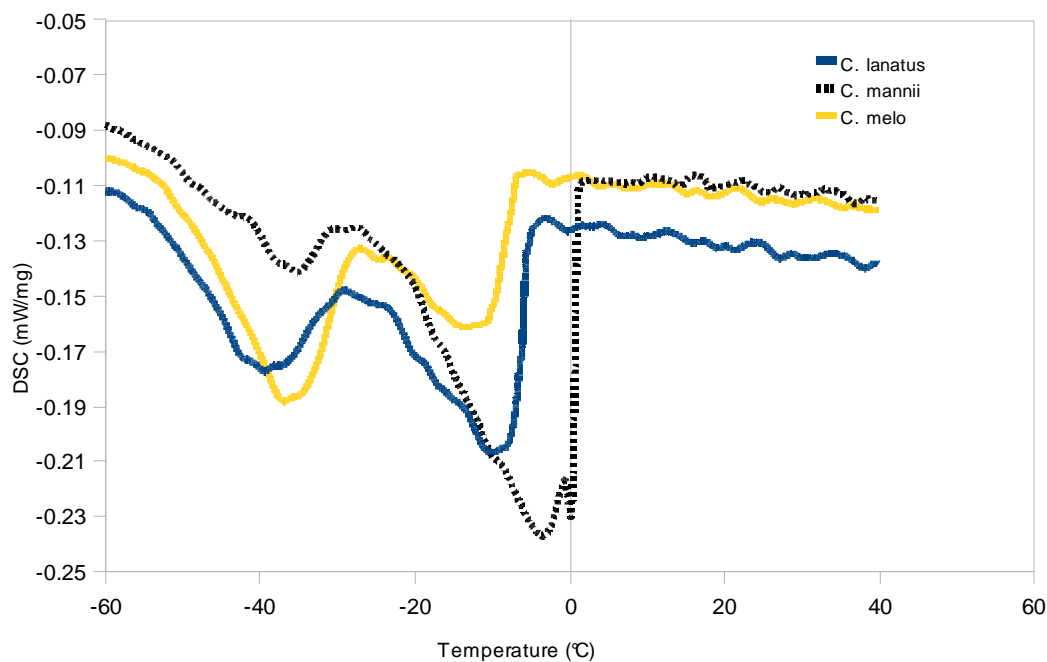
Figure 2: DSC cooling curves of cucurbit seed oils at cooling rate of 5 °C/min.

Table 1: Physical characteristics and proximate composition of indigenous cucurbit seeds.

		C. melo	*C. mannii*	*C. lanatus*
Morphology (n = 100)	Weight (g)	0.012 ± 0.003^a	0.184 ± 0.006^c	0.045 ± 0.005^b
	Length (cm)	0.55 ± 0.05^a	1.95 ± 0.06^c	1.22 ± 0.21^b
	Width (cm)	0.34 ± 0.02^a	0.80 ± 0.10^c	0.45 ± 0.10^b
Components (g/100 g of dry product)				
Dry matter (%)		95.66 ± 0.37^a	95.30 ± 0.13^a	96.16 ± 0.64^a
Crude protein (%) $^{N \times 6.25}$		37.30 ± 1.30^c	35.60 ± 0.14^b	28.6 ± 0.15^a
Total lipid (%)		36.50 ± 1.50^a	35.70 ± 1.20^a	46.40 ± 0.40^c
Ash (%)		3.11 ± 0.11^b	3.70 ± 0.20^c	2.45 ± 0.02^a

	C. melo	C. mannii	C. lanatus
Carbohydrate (%)	23.00 ± 1.20^b	25.00 ± 1.02^c	22.40 ± 1.00^a
Energy density (kcal/ 100 g of initial product*)	526.5 ± 5.3^a	499.4 ± 10.7^a	572.0 ± 3.7^b

Mean ± standard deviation of three determinations. In the same row, mean values followed by the same letter (superscript) are not significantly different (P >0.05).
n: sample size
*Sun-dried cucurbit seeds.

Table 2: Mineral content of indigenous cucurbit seeds (mg/100 g of initial product).

Mineral elements	*C. melo*	*C. mannii*	*C. lanatus*
K	640.20 ± 10.00^b	806.10 ± 21.21^c	500.00 ± 40.00^a
Na	28.00 ± 4.11^b	11.00 ± 2.31^a	43.00 ± 5.00^c
Ca	1426.00 ± 50.10^c	102.03 ± 15.60^b	46.00 ± 4.00^a
Mg	202.00 ± 15.00^a	366.00 ± 11.00^c	276.00 ± 23.00^b

Mean ± standard deviation of three determinations. In the same row, mean values followed by the same letter (superscript) are not significantly different (P >0.05).

Table 3: Chemical characteristics of cucurbit seed oils.

Characteristic	Oil types		
	C. melo	*C. mannii*	*C. lanatus*
Peroxide value (meq of O_2/kg of oil)	2.72 ± 0.04^a	9.78 ± 0.10^c	3.35 ± 0.05^b
Iodine value (g of I_2/100 g of oil)	115.50 ± 0.3^a	111.80 ± 2.00^a	113.00 ± 3.00^a
Acid value (mg of NaOH/g oil)	2.30 ± 0.00^a	2.30 ± 0.02^a	4.30 ± 0.20^b
Free fatty acid (% of oleic acid)	$1.13 \pm 0,00^a$	1.13 ± 0.01^a	2.15 ± 0.12^b
Unsaponifiable matter (%)	0.53 ± 0.04^a	0.55 ± 0.02^a	0.54 ± 0.10^a
Colour parameters L*	76.12 ± 0.05^c	67.50 ± 0.03^a	74.08 ± 0.01^b
a*	-3.55 ± 0.01^b	-3.70 ± 0.03^c	-2.93 ± 0.01^a
b*	$+13.00 \pm 0.02^b$	$+11.24 \pm 0.01^a$	$+17.95 \pm 0.02^c$
Chroma	0.08 ± 0.01^a	0.09 ± 0.00^a	0.06 ± 0.00^b

Hue angle	-74.84 ± 0.15^b	-71.78 ± 0.15^a	-80.73 ± 0.01^c
Colour	Pale yellow	Green-yellow	Yellow-orange
Bulk density (g/mL)	0.95 ± 0.01^a	0.95 ± 0.01^a	0.94 ± 0.01^a
Specific gravity	0.96 ± 0.02^a	0.96 ± 0.01^a	0.95 ± 0.01^a

Mean ± standard deviation of three determinations. In the same row, mean values followed by the same letter (superscript) are not significantly different (P >0.05).

Table 4: Main fatty acid composition of cucurbit seed oils (% total fatty acids).

Fatty acids	*C. melo*	*C. mannii*	*C. lanatus*
16:0	10.66 ± 0.08^a	16.33 ± 0.29^a	11.87 ± 0.18^a
18:0	9.02 ± 0.01^a	13.89 ± 0.22^a	9.35 ± 0.16^a
C18:1n 9	9.12 ± 0.03^a	14.54 ± 0.13^a	14.43 ± 0.11^a
18:2n 6	70.76 ± 0.02^a	54.81 ± 0.13^a	63.94 ± 0.23^a
18:3n 3	0.46 ± 0.01^a	0.42 ± 0.02^a	0.43 ± 0.01^a
TSFA	19.68 ± 0.04^a	30.22 ± 0.50^a	20.97 ± 0.24^a
MUFA	9.02 ± 0.01^a	14.54 ± 0.13^a	14.50 ± 0.15^a
PUFA	71.22 ± 0.02^a	55.23 ± 0.14^a	64.54 ± 0.11^a
TUFA/TSFA	4.10 ± 0.05^a	2.30 ± 0.02^a	3.81 ± 0.20^a
C18:0/C16:0	0.85 ± 0.01^a	0.85 ± 0.03^a	$0.79\ 0.01^a$

Mean ± standard deviation of three determinations. In the same row, mean values followed by the same letter (superscript) are not significantly different (P > 0.05). MUFA, monounsaturated fatty acids, PUFA, polyunsaturated fatty acids, TUFA, total unsaturated fatty acids, TSFA, total saturated fatty acids.

Table 5: Transition temperatures during melting and cooling processes of cucurbits seed oils.

Curve	Sample	Transition temperature (°C)			
		1	**2**	**3**	**4**
Melting	*C. melo*	-42.3 ± 0.1^b	$-37.3 \pm 0.3^{b*}$	-11.7 ± 0.1^a	-4.3 ± 0.7^b
	C. mannii	-30.0 ± 0.0^a	-20.3 ± 0.8^c	2.5 ± 0.8^a	
	C. lanatus	-36.5 ± 1.5^a	-18.1 ± 0.3^b	-8.8 ± 0.1^c	-1.6 ± 0.1^a
Crystallization	*C. melo*	-13.0 ± 0.3^b	-36.5 ± 0.5^a		
	C. mannii	-3.5 ± 0.1^a	-35.0 ± 0.2^a		
	C. lanatus	-10.2 ± 0.2^c	-39.5 ± 0.5^b		

Mean ± standard deviation of three determinations. In the same row, mean values followed by the same letter (superscript) are not significantly different (P >0.05).   * Exothermic peak.

Table 6: Comparison of thermal characteristics of cucurbit species seed oils.

Curve	Sample	Characteristics		
		T_{on} (°C)	T_{off} (°C)	ΔH (J/g)
Melting	C. melo	-48.7± 1.5	1.4 ± 0.3	39.0.± 1.1
	C. mannii	-39.5 ± 2.5	13.8 ± 0.3	47.8 ± 0.9
	C. lanatus	-47.7± 1.2	6.0 ± 1.7	56.0 ± 3.0
Crystallization	C. melo	-7.2 ± 0.5	ND	-24.0 ± 0.2
	C. mannii	1.3 ± 0.2	ND	-33.0± 1.0
	C. lanatus	-4.4 ± 0.4	ND	-25.5 ± 2.3

Values are means ± standard deviation of three determinations.
ND: not detected.

DISCUSSION

The proximate composition (total crude protein, total crude oil and total carbohydrate) of cucurbit seeds was similar to the composition of cucurbit seeds reported previously (Loukou et al., 2007) and they were higher than amounts reported by others. Nyam et al. (2009) reported that *Kalahari* melon (*C. lanatus*) seeds yielded 24.5% of protein, 30.5% of oil and 3.3% of total carbohydrates. De Mello et al. (2000) reported that melon seeds (*C. melo* hybrid AF-522) from Brazil contained 30.83% of oil, 14.91% of proteins and 22.94% of carbohydrates. Variation in proximate composition of the cucurbit seeds of the same species may be due to the differences in the variety of plant, cultivation climate and the harvesting time of the seeds (Nyam et al., 2009).

The high contents of oil, protein and carbohydrate of cucurbit seeds make them highly energetic. The high percentage of oil makes these seeds suitable for oil industry application.

The levels of these minerals of cucurbit seeds were higher than values found by Besbes et al. (2004) for two varieties of date seeds (Potassium: 229-293 mg/100 g; magnesium: 51.7-58.4 mg/100 g; sodium: 10.25 and 10.40 mg/100 g, calcium: 28.9 and 38.8 mg/100 g). The mineral contents of cucurbit seeds were also much higher than those found by Onyeike and Ancheru (2002) for groundnut and palm kernel. Data showed that cucurbit seeds were an important source of many mineral elements.

The peroxide value and the free fatty acids were among the important characteristics to determine the present condition and quality of oil sample. The high value of peroxide value of *C. mannii* oil shows that it is more unstable than the two other cucurbit seed oils. These values are lower than values for groundnut oil (20.0 meq O_2/kg of oil) reported by Onyeike and Ancheru (2002) and for *Astorcarpus heterphyllus* seed oil (15.0 meq/kg of oil) reported by Ajayi (2008). Tan et al. (2002) reported the peroxide values of some edible oils: canola oil (6.68 meq O_2/kg of oil), olive

oil (8.50 meq O_2/kg of oil), refined-bleached-deodorized palm plein (0.82 meq O_2/kg of oil) and sunflower oil (9.10 meq O_2/kg of oil). Oil whose peroxide value was lower than 10 meq O_2/kg of oil, was recommended for edible vegetable oils by Codex Alimentarius Commission (1982). According to Ojeh (1981), oils with high peroxide values are unstable and easily become rancid (having a disagreeable odour). The peroxide value of cucurbit seed oils studied in the present work suggests that they can be stored for long period without deterioration. The iodine value indicated the degree of unsaturation of seed oil. Iodine values of cucurbit seeds investigated here, were higher than iodine value of groundnut seed oil, 11.2 and palm kernel oil, 33.3 found by Onyeike and Ancheru (2002). They were comparable to the values found by Badifou (1991a) for *C. mannii* (110.9), for *L. sicceraria* var. 1 (115) and for *L. sicceraria* var. 2 (122.9). The higher iodine values for the species in this study were due to their high content in total unsaturated fatty acids mainly linoleic acid.

The total acidity of these oils varied from 2.30 to 4.30 (Table 3), showing that these oils could be considered as edible oils and could have long shelf life. The free fatty acid values of oils investigated were comparable of the value of sesame oil (2.37%) reported by Tan et al. (2002). According to Dosunmu and Ochu (1995), the *Chryosophyllum albidum* seed oil with free fatty acid reached to 1.81% and the *Cola rostata* seed oil with 5.0% supported the point of view that these oils are edible.

The lightness (L*) of *C. melo* and *C. lanatus* seed oils showed that they contained more yellow pigments and *C. mannii* seed oil contained more chlorophyll pigments. The fatty acid composition patterns of investigated cucurbit seed oils are characteristic of most species of cucurbits published by other authors (Badifou, 1991a; De Mello et al., 2001). Linoleic acid is one of the most

important polyunsaturated fatty acids (n-6) in human food because of its positive health benefit and also its essential fatty acid for human (Omode et al., 1995; Pastor-Cavada et al., 2009). In this study, the total polyunsaturated fatty acids of *C. melo* is higher than total polyunsaturated fatty acids (51.79%) of *C. melo* oil reported by De Mello et al. (2001).

On the nutritional aspect, consumption of foods rich in saturated fatty acids from C12 to C16 was positively associated with low-density lipoprotein and cardiovascular disorders, whereas C18:0 was considered neutral in this respect (Schaefer, 1997). According to Emken (1994), C18:0 was less hypercholesterolemic than C16:0. The amount of unsaturated n-6 was very high in the three oils, therefore the TUFA/TSFA ratio ranged from 2.30 to 4.10% of investigated oils was higher than the ratio recommended by FAO report (1994) which was between 0.84% and 1.16%.

The DSC melting and cooling curves of the three cucurbits seed oils were characterized by the presence of multiple endothermic and exothermic peaks. According to Tan and Che Man (2002), It was due to a variety of reasons in which two major causes predominate: the first was the unique features in the triacylglycerol (TAG) distribution and the other was the melting-recrystallization of the original TAG crystallites and their subsequent melting known as the polymorphism phenomenon. As the oil samples are heated, some of the less thermally-stable polymorphs melt; the remaining TAG rearrange and recrystallize into more stable polymorphs that melt at higher temperatures. On the other hand, when a partial melting of a polymorph, accompanied by conversion or transition to a higher polymorph takes place, both endothermic peak and endothermic changes are represented in a single endothermic peak. That can explain the phenomenon that

occurred with the *C. melo* seed oil heating curve which exhibited exothermic peak at -37.3 °C before melting phenomenon during heating process.

The low melting temperatures, (from -43.0 °C to -30 °C) might be attributed to highly unsaturated TAG rich in linolenic and linoleic acids. The transition temperatures (from -20.0 to -8.8) might be attributed to the unsaturated TAG rich in linoleic acids and the high melting temperatures for TAG rich in saturated fatty acids. Generally, the oil samples with high content of unsaturated fatty acid showed DSC melting and crystallization profiles at lower temperature regions (onset and offset temperatures) and required less energy during the melting process compared to the oil samples with high content of saturated fatty acids. Enthalpy of oil explains whether oil changes from one physical state to another by absorbing (endothermic) or releasing (exothermic) heat (Zhao and Yalkowsky, 1999). The data obtained are useful to control fractionation of oil during industrial production.

Conclusion

In general, the three species of cucurbit seeds investigated in this study are good sources of nutrients: proteins, oils, carbohydrates and mineral elements. The knowledge of the characteristics of their oils seems interesting for industrial and nutritional application, for example in feeding supplementation. The high linoleic content of these seed oils makes them nutritionally valuable. The *C. melo* seed oil contains the highest amount of unsaturated fatty acid and the *C. mannii* seed oil contains the highest amount of saturated fatty acids. *C. melo* seed oil exhibited a lowest melting point compared to *C. lanatus* and *C. mannii* seed oils. These thermal properties could be used in the industrial fractionation. Due to their similarity to the common used edible oils, this study suggests that the cucurbit seed oils may be used as edible oils.

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