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ORIGINAL PAPER

A Comparative Study of the Properties of Six Sudanese Cucurbit Seeds and Seed Oils

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Abstract The proximate analysis of seeds and physicochemical properties of oils extracted from six Sudanese cucurbit seeds *Cucumis mello* var. *agrestis*, *Cucumis melo* var. *flexuosus*, *Cucumis sativus, Citrullus lanatus* var. *colocynthoides, Cucumis prophetarum*, and *Luffa echinata* were examined by established methods. For each variety, the proximate analysis showed ranges for moisture, protein, and carbohydrates as 3.70–6.87, 14.50–17.50, and 15.62–28.89% on a dry matter basis, respectively. The oils were extracted by Soxhlet using petroleum ether, with yields that ranged from 10.9 to 27.10% (wt/wt). The obtained extracted oils were subjected to phyiscochemical, fatty acid, and tocopherol analysis. The physicochemical characterization of the oil revealed that the refractive indices and relative densities of the oils fell within the narrow ranges of 1.334–1.442 and 0.874–0.920 g/cm^3, respectively. Unsaponifiable matters ranged between 0.8 and 1.2 mg KOH/g, whilst peroxide values (PV) ranged from 2.3 to 4.1 meq/kg. The ranges of the values for free fatty acid (FFA %) were 1.2–4.0%. The predominant fatty acids were 16:0, 18:0, 18:1, and 18:2 with ranges of 8.9–14.2, 6.0–9.4, 14.6–32.1, and 43.6–65.5%, respectively. γ-Tocopherol was the predominant tocopherol in all samples ranging from 0.8 to 43.2% of the total tocopherols, followed by δ-tocopherol and α-tocopherol.

Keywords Cucurbits · Fatty acids · Seed oils · Tocopherols · *Cucumis sativus* · *Cucumis mello* · *Citrullus lanatus* var. *colocynthoide* · *Cucumis prophetarum* · *Luffa echinata*

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Introduction

The Cucurbitaceae or cucurbits family (also commonly referred to as the cucumber, gourd, melon, or pumpkin family) is a medium-sized plant family, primarily found in the warmer regions of the world. It is a family of economically important species, of which the fruits are used for nutrition and medicinal purposes [1]. Many Cucurbitaceae seeds are rich in oil and protein, and although none of these oils has been utilized on an industrial scale, many are used as cooking oil in some countries in Africa and the Middle East [2]. *Citrullus lanatus* var. *colocynthoide* is one of the species which is available in considerable amounts in Sudan. It is an ancestor type of the cultivated watermelon. It is locally known as "Gurum" and is semi-cultivated on the shores of the River Nile in the north of Sudan. The green parts of the plant are used as animal feeds, the seeds are used as snacks and as a masticatory article, and the residues are used as a source of heat energy for cooking [3].

Cucumis melo L. var. *flexuosus*, the snake melon, known in Sudan as "Agoor", is very popular salad plant the fruit of which contains some amounts of carbohydrates, minerals, and vitamins [4]. *Cucumis melo* var. *agrestis*, wild melon, is widely distributed in Sudan and used as a salad crop instead of cucumber in Western states where locally is known as "Tibbish"; the seeds contain between 12.5 and 39.1% oil [5]. *Luffa echinata* is widely distributed in Sudan and is locally known as "Umshwaika"; its oil is found to deposit the hydrocarbon, hentriacontane, $C_{31}H_{64}$. Saponin has been isolated in partially purified form, and the sapogenin is identified as gypsogenin [6]. Datiscacin, cucurbitsacin B, and cucurbitsacin S were isolated from the fruits of *Luffa echinata* for the first time by Ahmad et al. [7]. Several authors [2, 8–10] have reported studies on species of the Cucurbitaceae family and compared the physicochemical characteristics of their oils with those from conventional sources. Mariod and Mattahus [5] reported fatty acid composition of oil extracted from Sudanese *Cucumis melo* var. *agrestis* contained an average 61.4% linolenic, 16.4% oleic, 9.7% palmitic, and 9.8% stearic acids. The conventional sources for vegetable oils in Sudan are limited to a few oilseeds, e.g., groundnut, sesame, sunflower, and cottonseed, and no longer meet the increasing demand for domestic and industrial purposes. Therefore, the need exists to look for new resources to meet this demand.

The present study was undertaken to determine the properties of six Sudanese cucurbit seeds and seed oils, whose seeds are traditionally used as food or as a prophylactic remedy against various diseases in Sudan.

Materials and Methods

Plant Materials

Fruits of *Cucumis melo* var. *agrestis* and *Cucumis melo* L. var. *flexuosus* were collected from local markets, Khartoum North (Sudan), while fruits of *Cucumis sativus, Citrullus lanatus* var. *colocynthoide*, *Cucumis prophetarum* L. and *Luffa echinata* were collected from wild plants growing in the northern part of Omdurman town, Khartoum state, Sudan, in March 2007. The plants were identified by Prof. Dr. Dhaw Albait Abdallah, Taxonomist, Department of Plant Protection, College of Agricultural Studies, Sudan University of Science and Technology (Sudan). The fruits were separated into seeds and pulp by hands, and were dried to constant weight at 50°C in drying oven (FD 115; Fisher Scientific, Loughborough, Leicestershire, UK).

Fruit Analyses

Fruit Length and Fruit Size (Diameter)

The length and diameter of 20 fresh fruits (in cm) were evaluated using a dial caliper (Precision Graphic Instruments, USA), following the method of Montiel-Herrera et al. [11].

Dry Fruit, Pulp and Seed Weights

The weight of 20 randomly chosen dried whole fruits was determined using an analytical balance (Mettler-Toledo, Columbus, OH, USA). The pulp and seeds of 20 dried fruits, which were separated manually, were collected in a Petri dish and the weight was determined in the same manner.

Protein, Moisture, Ash and Lipid Analysis

Protein, moisture and ash were determined according to the standard methods of the Association of Official Analytical Chemists (AOAC) [12]. Forced draft oven BS (Model OV-160; Gallenkamp, England) was used for determination of moisture and volatile matter under the conditions of the test with the temperature adjusted to 130 ± 2°C. Proteins were calculated from the nitrogen content by the Kjeldahl method using the conversion factor 6.25. Ash was determined by incinerating at 500°C in a muffle furnace for 6 h. Crude fiber was estimated by standard methods of the AOAC [12]. The total carbohydrate content (on dry weight basis) was calculated by difference [100 − (protein + lipids + ash + crude fiber)].

Oil Extraction

Seeds (10 g) were ground using blender (Waring, Torrington, CT, USA) at high speed for approximately 2 min. The oil was extracted from the ground seeds by extraction with petroleum ether (60–80°C) in a Soxhlet apparatus for 6 h following the AOCS Official Method no. Am 2-93 [13]. The ratio of solids to solvent used was 1:10. The oil was then recovered by evaporating off the solvent using rotary evaporator Model N-1 (Eyela; Tokyo Rikakikal, Japan) and residual solvent was removed by flushing with 99.9% nitrogen. The obtained oil was stored at 4°C until further investigation.

Fatty Acid Composition

The fatty acid composition of the oil from six Sudanese cucurbits was determined following the ISO draft

standards [14]. In brief: one drop of the oil was dissolved in 1.0 mL of *n*-heptane, 50 µl 2 M sodium methanolate in methanol were added, and the closed tube was agitated vigorously for 1.0 min. After addition of 100 µL of water, the tube was centrifuged at 4,500*g* for 10 min. and the lower aqueous phase was removed. After that, 50 µL of 1 M HCl were added to the heptane phase, the two phases were briefly mixed, and the lower aqueous phase was rejected. About 20 mg of sodium hydrogen sulphate (monohydrate, extra pure; Merck, Darmstadt, Germany) were added, and after centrifugation at 4,500*g* for 10 min, the top *n*-heptane phase was transferred into a vial and injected into a Varian 5890 gas chromatograph with a capillary column, CP-Sil 88 (100 m long, 0.25 mm ID, film thickness 0.2 µm). The temperature programme was: from 155°C heated to 220°C (1.5°C/min.), 10 min isotherm; injector 250°C, detector 250°C; carrier gas 1.07 mL/min hydrogen; split ratio 1:50; detector gas 30 mL/min hydrogen; 300 mL/min air and 30 mL/min nitrogen; manual injection volume less than 1 µL. The integration software computed the peak areas, and percentages of fatty acid methyl esters (FAME) were obtained as weight percent by direct internal normalization.

Tocopherols (TOC)

For determination of tocopherols, a solution of 250 mg of the oil of six Sudanese cucurbits in 25 mL *n*-heptane was directly used for the HPLC. The HPLC analysis was conducted using a Merck-Hitachi low-pressure gradient system, fitted with an L-6000 pump, a Merck-Hitachi F-1000 Fluorescence Spectrophotometer (detector wavelengths for excitation 295 nm, for emission 330 nm) and a D-2500 integration system; 20 µL of the samples were injected by a Merck 655-A40 Autosampler onto a Diol phase HPLC column 25 cm × 4.6 mm ID (Merck) using a flow rate of 1.3 mL/min. The mobile phase used was *n*-heptane/tert, butyl methyl ether (99 + 1, v/v) [15].

Physicochemical Characteristics

The following physicochemical characteristics of the oils of *Cucumis sativus, Cucumis mello* var. *agrestis, Citrullus lanatus* var. *colocynthoides, Cucumis prophetarum, Cucumis melo* var. *flexuosus*, and *Luffa echinata* were determined following the AOCS Official methods [12] as given below.

Color

AOCS Official Method no. Cc 13e-92 [12] was followed to determine the oil color. Lovibond tintometer (Model E, supplied by Griffin and George, Salisbury, England) and 5.25-inch cell were used for oil color determination. The color was expressed in yellow (Y), and red (R).

Refractive Index

AOCS Official Method no. Cc7-25 [12] was followed to determine the refractive index of the oils at 40°C.

Specific Gravity

AOCS Official Method no. Cc 10 a-25 [12] was followed for determination of specific gravity of oils at 30°C**.**

Free Fatty Acids

Free fatty acid (FFA%) was determined using the AOCS Official Method no. Ca 5a-4. [12].

Peroxide Value

Peroxide values of the flaxseed oils were determined according to AOCS Official Method no. Cd 8-53 [12].

Unsaponifiable Matter

Unsaponifiable matter of the flaxseed oils was determined according to AOCS Official Method no. Ca 6a-40 [12].

Iodine Value

Iodine value was calculated following the method of Kyriakidis and Katsiloulis [16] using the percentages of fatty acid methyl esters and a general equation with specific coefficients Calculated IV:

$$\mathrm{IV} = xC_1 + yC_2 + zC_3$$

where: C_1, C_2, and C_3 correspond to the sum of relative percentage concentrations of the unsaturated fatty acids with one, two, and three double bonds, respectively, and *x, y,* and *z*, are coefficients that must be determined for each type of oil.

Statistical Analysis

All experiments were carried out in triplicate unless otherwise stated; results are expressed as means ± SD. Statistical analysis was carried out using a one-way ANOVA with a significance level of $p < 0.05$. The software used for the statistical analysis was the SPSS for Windows statistical package (v.10.0.6; SPSS, Chicago, IL, USA).

Results and Discussion

The Fruit Characteristics

The fruit characteristics of six Sudanese cucurbits are presented in Table 1. The differences among the cucurbits in dry fruit weight were found to be significant ($p \leq 0.05$). *Cucumis melo* var. *flexuosus* was found to be the highest in dry fruit weight (65 g) followed by *Cucumis melo* var. *agrestis* (38 g) and *Citrullus lanatus* var. *colocynthoide* (14.8 g), while *Luffa echinata* dried fruit weighed only 1.2 g. The fruit length and size (diameter) ranged from 2.7 to 30.0 and from 1.9 to 13.0 cm, respectively. The weight of dried seeds in *Cucumis melo* var. *flexuosus* again was found very high (19.5 g) in comparison to other cucurbits and these weights ranged from 0.45 to 19.5 g, while the weight of dried bulb ranged from 0.75 to 45.5 g as presented in Table 1. The dried pulp of *Cucumis melo* var. *flexuosus* represents more than 70% of its original weight followed by *Citrullus lanatus* var. *colocynthoide* (68.9%) and *Cucumis sativus* (66.1%), *Cucumis melo* var. *agrestis* (65%), *Cucumis prophetarum (64.5%)* and *Luffa echinata* (62.5%), respectively. From our observations during sample collection, we noticed that these cucurbits are very similar in aboveground development and root habit, but they are extremely diverse for fruit characteristics. Seeds of cucurbits can usually be readily separated from the stringy pulp to which they are attached. Sometimes a light fermentation for 24–72 h of the wetted seeds is useful to clean the seeds of pulp. The cleaned seeds can be processed for use or dried for storage. Fresh, wet seeds are sometimes chewed without further processing. They can also be toasted, with or without light salting. Or, they can be cooked into soups with or without removing hulls [17].

Proximate Chemical Analysis

The protein, moisture, ash and lipid analysis of six Sudanese cucurbits are presented in Table 2. The six samples showed significant differences ($p \leq 0.05$) in all analyzed constituents of the proximate composition. The *Cucumis sativus* seeds showed the highest level in protein content with 17.5 g/100 g, followed by *Cucumis melo* var. *agrestis* with 16.62 g/100 g, while *Cucumis prophetarum* showed the highest levels in moisture, carbohydrate and ash content at 6.87, 28.82 and 8.33 g/100 g, respectively. The protein

Table 1 Fruit properties of six Sudanese cucurbits

Sample	Dry fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Seed weight (g)	Weight of bulb (g)
Citrullus lanatus var. *colocynthoide*	14.8 ± 0.12^{c}	13.0 ± 0.15^{c}	13.0 ± 0.12^{a}	4.6 ± 0.17^{c}	10.2 ± 0.17^{c}
Cucumis prophetarum	9.6 ± 0.17^{d}	7.0 ± 0.17^{d}	4.0 ± 0.17^{d}	3.4 ± 0.17^{c}	6.2 ± 0.17^{d}
Cucumis sativus	6.2 ± 0.17^{e}	6.0 ± 0.17^{d}	3.0 ± 0.17^{d}	2.1 ± 0.17^{d}	4.1 ± 0.17^{e}
Luffa echinata	1.2 ± 0.17^{f}	2.7 ± 0.17^{e}	1.9 ± 0.17	0.45 ± 0.17^{e}	0.75 ± 0.17^{f}
Cucumis melo var. *flexuosus*	65.0 ± 0.17^{a}	30.0 ± 0.17^{a}	10.0 ± 0.17^{b}	19.5 ± 0.17^{a}	45.5 ± 0.17^{a}
Cucumis melo var. *agrestis*	38.0 ± 0.1^{b}	14.8 ± 0.17^{b}	8.8 ± 0.17^{c}	13.3 ± 0.17^{b}	24.7 ± 0.17^{b}

Values are means ± SD of 20 samples analyzed in duplicate; $n = 20$. Values with different superscript letters within a column indicate significant differences at $p > 0.05$

Table 2 Proximate analysis (g/100 g) of six Sudanese cucurbit seeds

Sample	Moisture	Protein	CHO	Fat	Fiber	Ash
Citrullus lanatus var. *colocynthoide*	4.17 ± 0.17^{c}	15.75 ± 0.25^{c}	17.01 ± 0.22^{d}	27.10 ± 0.26^{a}	31.34 ± 0.23^{c}	4.62 ± 0.13^{d}
Cucumis prophetarum	6.87 ± 0.21^{a}	14.50 ± 0.22^{d}	28.82 ± 0.15^{a}	10.9 ± 0.15^{e}	31.58 ± 0.24^{c}	8.33 ± 0.16^{a}
Cucumis sativus	4.41 ± 0.18^{c}	17.50 ± 0.31^{a}	22.37 ± 0.13^{b}	25.85 ± 0.25^{ab}	25.86 ± 0.17^{d}	4.01 ± 0.18^{e}
Luffa echinata	5.17 ± 0.25^{b}	15.75 ± 0.25^{c}	20.06 ± 0.15^{c}	23.80 ± 0.28^{c}	31.81 ± 0.21^{c}	3.41 ± 0.11^{e}
Cucumis melo var. *flexuosus*	3.70 ± 0.15^{d}	15.75 ± 0.25^{c}	16.19 ± 0.25^{e}	22.33 ± 0.18^{d}	36.04 ± 0.22^{a}	5.69 ± 0.12^{b}
Cucumis melo var. *agrestis*	4.77 ± 0.11^{b}	16.62 ± 0.16^{b}	15.62 ± 0.21^{e}	23.33 ± 0.20^{c}	34.36 ± 0.22^{b}	5.30 ± 0.21^{c}
Groundnut	3.0	25.3	26.1	40.1	3.1	2.4
Sesame	4.3	18.3	12.4	59.6	3.6	1.8
Sunflower	4.1	21.2	12.2	34.4	24.1	4.0

Values are means ± SD of three ($n = 3$) measurements. Values with different superscript letters within a column indicate significant differences at $p > 0.05$

Source: Ensminger et al. [18]

concentrations of the studied cucurbits were within the range 14.5–17.5 g/100 g, which is slightly less than protein levels in most oily seeds [18]. *Citrullus lanatus* var. *colocynthoide* seeds showed higher level in lipid 27.1 g/100 g followed by *Cucumis sativus* and *Luffa echinata* showing 25.8 and 23.8 g/100 g, respectively. The carbohydrates, fibre, and ash analysis were found low in comparison with sesame, ground nut, and sunflower [18]. Oil content of different species of cucurbits has shown a wide range of variation from 10.9 to 27.1% which indicated very clearly that the *Cucurbitaceae* formed a potential source of oils, and fats. Further, it would be seen that in all species, the oil content was lower than most Sudanese conventional oil seeds (cottonseed, sunflower, sesame, and groundnut) [17]. In 2008, Mariod and Matthaus [5] reported an oil content of 31.0% for *Cucumis melo* var. *agrestis* which was higher than that reported in this study. Ziyada and Elhussien [3] studied the seeds of *Citrullus lanatus* var. *colocynthoide* and they found that the oil content was 35.5 g/100 g which was higher than the 27.10 g/100 g reported in this study.

In addition, the oils obtained from most of the species were odorless, of good color, and of good appearance. Besides the oil content, the seeds of the cucurbits have been found to be a rich source of protein: the seeds of the different species have been found to contain protein ranging from 14.5 to 17.5%, which is less than the range of most conventional oil seeds, such as sesame, cottonseed, and sunflower which contain about 18.3–25.3% protein [18]. All the cucurbits with the exception of *Luffa echinata and Cucumis prophetarum* produced a very satisfactory vegetable curd. In Western Sudan, the curd from *Citrullus lanatus* called Bajbaji, which is very popular as an infant and child food. The curds were rich in protein and oil and contained no more than minor and insignificant traces of the seed coat. However, the vegetable curds are usually very fine and difficult to separate from the whey by filtration [17].

Thus, preliminary consideration of cucurbit seeds as sources of vegetable oils and proteins are promising. Further extensive studies are needed to select appropriate species and varieties, and to develop appropriate techniques at the household level.

Chemical and Physical Characteristics of the Crude Oils

Some of the chemical and physical characteristics of crude oils extracted from six Sudanese cucurbits are presented in Table 3. The six samples were significantly different ($p \leq 0.05$) in their refractive indices. *Cucumis melo* var. *agrestis* showed the highest refractive index of 1.442 followed by *Cucumis melo* var. *flexuosus, Cucumis sativus, Citrullus lanatus* var. *colocynthoide*, *Cucumis prophetarum,* and *Luffa echinata*. The refractive indices of the test cucurbit seed oils are not comparable with Codex standards [19] for soybean (1.466–1.470), sunflower (1.461–1.468), groundnut (1.460–1.465), cotton seed (1.458–1.466), and sesame (1.460–1.465) oils. The refractive indices of cucurbit seed oils are less than recommended by Codex standards [19] for vegetable oils. Refractive indices in oils tend to increase with the decrease of double bonds, i.e. with mean unsaturation. In general, the refractive indices of natural fats and oils are related to their average degree of unsaturation in an approximately linear way. The relationship between refractive index and the iodine acid, and saponification values is somewhat more complex [20].

The specific gravity values of the oils are presented in Table 3. The relative density values were different from other Cucurbitaceae reported by other authors [5, 8, 9, 22]. The relative density values ranged from 0.884 to 0.920 with *Cucumis melo* var. *flexuosus* as the highest followed by *Luffa echinata*, *Cucumis sativus*, and *Cucumis melo* var. *agrestis*, while *Citrullus lanatus* var. *colocynthoide* and *Cucumis prophetarum* are the lowest in relative density.

The six samples were high in unsaponifiable matter (Table 3) ranging from 0.81 to 1.1, with *Cucumis melo* var. *flexuosus* showing the highest value followed by *Cucumis sativus* and *Cucumis prophetarum*, while peroxide values of 2.3–4.1 milliequivalents of active oxygen/kg oil and free fatty acids at 1.3–4.5% were comparable with other Cucurbitaceae reported by other authors [5, 8, 9, 22]. The Codex Alimentarius Commission [19] stipulated a permitted maximum peroxide level of not more than 10 meq peroxide oxygen/kg oil, e.g., groundnut, cottonseed, sesame, and sunflower oils.

Table 3 shows the color of oil samples from the six cucurbit species. The values are presented in the Lovibond Tintometer scale, the vegetable oil industry is familiar with the Lovibond color scale where the color scale used for measurement of color using our cucurbit oils is expressed in terms of Lovibond red and yellow units or values [21]. Crude oils seem to be dark in color as the color decreased through the processing steps [22] from Table 3. As was expected, all samples are dark in color and ranged between light dark yellow for *Cucumis sativus* (25 Y + 0.2 R), *Cucumis prophetarum* (30 Y + 0.6 R) to deep dark yellow for *Luffa echinata* (33 Y + 0.8 R), whereas *Cucumis melo* var. *agrestis*, *Cucumis melo* var. *flexuosus*, and *Citrullus lanatus* var. *colocynthoide* were dark red in color and their values in Lovibond scale were (35 Y + 2.2 R), (35 Y + 1.9 R), and (35 Y + 1.3 R), respectively. The color results obtained in this study were in disagreement with Badlfu [9], perhaps because of the different species. Color is an essential attribute of oils, particularly in Sudan, where most traditional dishes are prepared with crude oil.

Table 3 Physicochemical characteristics of the crude oil of six Sudanese wild cucurbit seed oils

Property Sample	Refractive index (40 ± 1 °C)	Color[a]	FFA%	Peroxide value (meq O_2/kg oil)	Unsaponifiable matter	Relative density (30 ± 1 °C)	Iodine value
Citrullus lanatus var. *colocynthoide*	1.429 ± 0.001[b]	35 Y + 1.3 R[b]	2.2 ± 0.1[b]	4.1 ± 1.2[a]	0.8 ± 0.1[ab]	0.886 ± 0.001[c]	112.7
Cucumis prophetarum	1.410 ± 0.001[c]	30 Y + 0.6 R[d]	1.9 ± 0.1[c]	2.3 ± 0.1[b]	0.9 ± 0.1[a]	0.884 ± 0.05[c]	110.6
Cucumis sativus	1.434 ± 0.002[b]	25 Y + 0.2 R[e]	1.3 ± 0.2[d]	3.5 ± 0.3[a]	1.1 ± 0.1[a]	0.914 ± 0.001[a]	114.0
Luffa echinata	1.409 ± 0.002[c]	33 Y + 0.8 R[c]	4.5 ± 0.3[a]	3.7 ± 0.2[a]	0.8 ± 0.1[ab]	0.918 ± 0.002[a]	100.1
Cucumis melo var. *flexuosus*	1.437 ± 0.001[a]	35 Y + 1.9 R[a]	2.8 ± 0.1[b]	2.8 ± 0.1[b]	1.2 ± 0.1[a]	0.920 ± 0.002[a]	111.5
Cucumis melo var. *agrestis*	1.442 ± 0.001[a]	35 Y + 2.2 R[a]	2.7 ± 0.1[b]	3.9 ± 0.1[a]	0.8 ± 0.1[ab]	0.908 ± 0.001[ab]	108.5

R Value on the red slide, *Y* value on the yellow slide. Values are mean of three replicate samples ($n = 3$), mean + SD. Values with different superscript letters within a column indicate significant differences at $p > 0.05$. Iodine value was calculated following Kyriakidis and Katsiloulis [16]

Table 4 Fatty acid composition (%) of six Sudanese cucurbit seed oils compared with commercial oils

Fatty acid	*Cucumis melo* var. *flexuosus*	*Luffa echinata*	*Cucumis sativus*	*Citrullus lanatus* var. *colocynthoide*	*Cucumis melo* var. *agrestis*	*Cucumis prophetarum*	Groundnut	Sesame	Sunflower
14:0	0.3 ± 0.1[a]	0.1 ± 0.1[a]	0.1 ± 0.2[a]	0.1 ± 0.1[a]	0.1 ± 0.1[a]	0.1 ± 0.2[a]	0.1 ± 0.2	0.1 ± 0.1	0.2 ± 0.2
16:0	12.9 ± 0.15[b]	14.2 ± 0.13[a]	8.9 ± 0.12[d]	10.7 ± 0.15[c]	10.8 ± 0.13[c]	14.1 ± 0.15[a]	8.0–14.0	7.9–12.0	5.0–7.6
18:0	6.0 ± 0.2[d]	8.6 ± 0.2[b]	9.3 ± 0.5[a]	9.0 ± 0.2[a]	9.4 ± 0.3[a]	7.2 ± 0.1[c]	1.0–4.5	4.5–6.7	2.7–6.5
18:1n-9	19.4 ± 0.15[c]	32.1 ± 0.12[a]	15.4 ± 0.13[e]	14.6 ± 0.15[e]	21.3 ± 0.15[b]	16.4 ± 0.21[d]	35.0–39.0	34.4–45.5	14.0–39.4
18:2n-6	61.4 ± 0.22[c]	43.6 ± 0.23[d]	65.5 ± 0.21[a]	64.9 ± 0.20[b]	57.6 ± 0.32[e]	61.4 ± 0.24[c]	12.0–43.0	36.9–47.9	48.3–74.0
18:3	ND[e]	1.0 ± 0.2[a]	0.4 ± 0.1[cd]	0.3 ± 0.1[cd]	0.3 ± 0.2 [cd]	0.8 ± 0.2[ab]	0.3	0.2–1.0	0.3
20:1	ND[c]	0.4 ± 0.2[ab]	0.4 ± 0.2[ab]	0.4 ± 0.2[ab]	0.5 ± 0.2[a]	ND[c]	0.7–1.7	0.3	0.1–0.5
∑SFA	19.2 ± 0.15[a]	22.9 ± 0.15[a]	18.3	19.8 ± 0.15[a]	20.3 ± 0.21[ab]	21.4 ± 0.15[c]	9.1–18.5	12.5–18.7	7.9–14.1
∑UFA	80.8	77.1	81.7	80.2	79.7	78.6	47.3–82.0	71.8–94.4	62.7–90.6
Ratio UFA/SA	4.2	3.4	4.5	4.1	3.9	3.7	4.4–5.2	5.0–5.7	6.4–7.9

Codex Stan 210-1999. All determinations were carried out in triplicate and mean value ± SD reported. SFA, saturated fatty acids. Values with different superscript letters within a row indicate significant differences at $p > 0.05$

UFA Unsaturated fatty acids, *ND* non-detectable, defined as ≤ 0.05%

The iodine value is a measure of the average amount of unsaturation of fats and oils and is expressed in terms of the number of centigrams of iodine absorbed per gram of sample (Wijs method) [13]. A proposed calculation method [16] was reported to give results in better agreement with the Wijs method. The calculated iodine values for the six cucurbit species are depicted in Table 3. From this table, *Cucumis sativus, Citrullus lanatus, Cucumis melo* L. var. *flexuosus* and *Cucumis prophetarum* showed higher iodine values followed by *Cucumis melo* var. *agrestis* and *Luffa echinata.*

The fatty acid composition observed in Table 4 clearly suggests that the cucurbit seed oils consist mainly of long-chain fatty acids (i.e., C18:2 and C18:1), as indeed is the case for groundnut, sesame, and sunflower oils. The range of calculated iodine values for the six cucurbit species, 100.1–114.0, is slightly higher than the range of iodine values for groundnut oil (86–107), but lower than the iodine value range for sesame (104–120) and sunflower oils 118–141[19].

Fatty Acid Composition

The ranges of fatty acid content in the six cucurbit species studied were broad; since environmental influences were largely eliminated, differences among species may be due to species–environment interactions. The fatty acid compositions of the cucurbit seed oils are given in Table 4, which shows the principal fatty acids to be palmitic (16:0), stearic (18:0), oleic (18:1n-9), and linoleic (18:2n-6) acids. From Table 4, the comparison between the cucurbit seed oils and the oils from groundnut, sesame, and sunflower is considerable. Palmitic and stearic acids composition in the cucurbit seed oils are higher than their content in the commercial oils. However, oleic acid content in the cucurbit seed oils is lower than its content in the commercial oils [19], while linoleic acid is comparable with those in sesame and sunflower oils (Table 4). Thus, the level of total saturation in the cucurbit seed oils is higher than that in the commercial oils. The unsaturation profiles

Table 5 Tocopherol composition (mg/100 g) of six Sudanese cucurbit seed oils compared with commercial oils

Sample	α-T	γ-T	δ-T	Total
Cucumis melo var. *flexuosus*	0.4 ± 0.05^{a}	33.5 ± 0.26^{c}	0.8 ± 0.05^{a}	34.7 ± 0.01^{c}
Luffa echinata	ND^{c}	0.8 ± 0.05^{e}	0.9 ± 0.6^{a}	1.7 ± 0.02^{e}
Cucumis sativus var argentea	ND^{c}	43.2 ± 0.25^{a}	0.1 ± 0.1^{b}	43.3 ± 0.05^{a}
Citrullus lanatus var. *colocynthoide*	ND^{c}	35.9 ± 0.21^{b}	1.0 ± 0.1^{a}	36.9 ± 0.15^{b}
Cucumis melo var. *agrestis*	ND^{c}	29.1 ± 0.6^{d}	ND^{c}	29.1 ± 0.12^{d}
Cucumis prophetarum	0.1 ± 0.3^{b}	0.3 ± 0.1^{e}	1.0 ± 0.2^{a}	1.4 ± 0.21^{e}
Ground nut	4.9–37.3	8.8–38.9	ND–2.2	17.0–130.0
Sesame	ND–0.33	52.1–98.3	0.4–2.1	33.0–101.0
Sunflower	40.3–93.5	ND–3.4	ND–0.70	44.0–152.0

Codex Stan 210-1999. All determinations were carried out in triplicate and mean value ± SD was reported. Values with different superscript letters within a column indicate significant differences at $p > 0.05$

T Tocopherol, *ND* non-detectable, defined as ≤0.05 mg/100 g

of the cucurbit seed oils are remarkably higher than those of sesame and ground nut oils but lower than that of sunflower oil, where both sets of seed oils have linoleic acid as the most abundant fatty acid, followed by oleic acid. In general, polyunsaturation in sunflower oil is higher than it is in the cucurbit seed oils because of its significant content of linoleic acid, 18:2n-6 (48.3–74.0%). In all cases, the only fatty acids present in detectable quantities were stearic, palmitic, oleic and linoleic acids.

Tocopherols Content of the Crude Oils

Tocopherols (α-, β-, γ-, and δ-tocopherol) are a group of fat soluble antioxidants with a chromanol ring and a hydrophobic side chain. Fats and oils and derived products are a major source of tocopherols. The tocopherols content of the crude oils from six cucurbit samples is given in Table 5. *Cucumis sativus*, *Citrullus lanatus* var. *colocynthoide* and *Cucumis melo* var. *flexuosus* had medium amounts of tocopherols when compared with other common oils [19] such as sesame oil, groundnut oil, or sunflower oil, in which the amount of tocopherols was ranged from 17.0 to 152 mg/100 g, while *Cucumis melo* var. *agrestis*, *Luffa echinata*, and *Cucumis prophetarum* contain low amounts when compared with groundnut, sesame, and sunflower oils. The main tocopherol of the six samples was γ-tocopherol which represent 47.1–100% of the total tocopherols, followed by α-tocopherol which represent up to 71.4%. The other tocopherols in the oil of the six samples were below 0.05 mg/100 g each.

Conclusions

Improved knowledge on the composition, analysis, and properties of *Cucumis melo* var. *agrestis*, *Cucumis melo* var. *flexuosus*, *Cucumis sativus, Citrullus lanatus* var. *colocynthoide*, *Cucumis prophetarum*, and *Luffa echinata* seeds would assist in efforts to achieve industrial application of these plants. Data about these seeds are very few, and there are no reports of the detailed bioactive composition of these seed oils. The major results from this study, as shown in Tables 1, 2, 3, 4, and 5, demonstrate the significant differences between the cucurbit seed oils and the oils from sesame, cottonseed, sunflower, and groundnut. The test cucurbit seeds have reasonably high oil contents (22.3–27.1%, except *Cucumis prophetarum*) with high unsaturation (more than 77.0%). The high amounts of polyunsaturated fatty acids may have favorable nutritional implications and beneficial physiological effect in the prevention of coronary heart disease and cancer. The test cucurbit seeds have good physicochemical properties that make them attractive candidates for commercial exploitation. These seed oils with high levels of γ-tocopherol may be as important as α-tocopherol in the prevention of degenerative diseases. The high tocopherol content, tocopherol quality, and hence high protection against oxidative stress, relatively good shelf life, and other desirable characteristics indicate potential uses of seed oil in food, pharmaceuticals, and cosmetics.

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