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# Chemical Properties of Some Cucurbitaceae Oils from Cameroon

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**Abstract:** This work presents some chemical properties of Cucurbitaceae seed oils from different areas in Cameroon. These seeds are *Cucumeropsis mannii* (egusi melon), *Cucurbita maxima* (pumpkin or squash gourd), *Cucurbita moschata* (musk melón), *Lagenaria siceraria* (bottle gourd or calabash) and *Cucumis sativus* ("Ibo"egusi). The results show that the saponification, iodine and peroxide indices are influenced by the areas while the acid index and percentage of impurity do not depend on the area of cultivation but on the specie, except *Lagenaria siceraria*. The values for the indices are within recommended levels for edible oils. These oils have 4 main fatty acids: Linoleic acid, C18:2 (49-69%); oleic acid, C18:1 (9-25%); stearic acid, C18:O (7-11%) and palmitic acid, C16:O (10-19%). Their chemical properties are similar to those of corn, cottonseed, sesame and sunflower seed oils, suggesting their potential use as good table and cooking oils which can increase HDL and reduce serum cholesterol and LDL levels, hence could help prevent cardiovascular illnesses. They could also be used for making mayonnaise and soap.

**Key words:** Cucurbitaceae, oils, lipids, fatty acids, saponification, iodine, peroxide, indices

## INTRODUCTION

The Cucurbitaceae family has a tremendous genetic diversity, extending to vegetative and reproductive characteristics (Ng, 1993). They grow in tropical, subtropical, arid deserts and temperate locations. The plants of the five varieties studied are annual, herbaceous, monoecious plants with climbing or creeping stems. In West Africa, the seeds are planted in the months of March to April. They are planted directly into the beds at about 120-200 cm between rows and between seeds. 3 seeds are planted per hole at a depth of 3 cm and they mature after 5 months (Akinsanmi, 1980). After planting, they completely cover the soil surface within 4 weeks of growth, thus helping in weed control. Pollination is by insects. Flowering occurs at about 4-5 weeks. The fruits are indehiscent smooth berries, are very large and seedy and when sound, can be stored for over a year, or the seeds can be removed, washed and dried. Sometimes a light fermentation for 1-3 days is useful to clean the stringy pulp from the seeds in order to ease the removal of the seeds. The cleaned seeds are washed and dried in the sun, at lowest settings in an oven or in the ceiling of traditional kitchens. The dried seeds are stored in bags and insect-free containers. For use, they are decorticated, ground into a nutritious oily meal and cooked. The seeds contain about 50% oil (Martin, 1998), 42-57% oil (Fokou *et al*., 2004), 44-54% oil for seeds cultivated in different bioclimatic regions in Cameroon (Achu *et al*., 2005). These studies show that these seeds contain good amounts of oil that can be exploited. Most of the oil is made up of unsaturated fatty acids with high amounts of essential fatty acids, especially linoleic acid, 68.5% (Kinkela, 1990). Pumpkin seed oils also have antihelmintic properties (Veljkovic, 1992). Considering this high nutritional value of egusi seed oils, they are still underexploited industrially in Cameroon. The aim of this study was to find out some of the chemical properties (acid, saponification, iodine, peroxide and fatty acid composition) of oils extracted from egusi seeds from Cameroon and the effect of the various regions of cultivation of these seeds on oil quality. These will enable the oils to be exploited by the industry and for alimentary purposes, with the eventual production and use of egusi seed oils. This will also lead to increased production, consumption and sale of these seeds especially in the rural areas where farming is the main occupation of the women, thus helping to improve their health and financial status.

## MATERIALS AND METHODS

**Sample collection and areas of collection:** The samples were collected from different bioclimatic areas of great cultivation in Cameroon (Table 1). A review of these areas of collection shows that there are two main vegetations in Cameroon: The Equatorial forest and the Tropical grasslands. The Equatorial forest consists of the Swamp forest and the Rain forest while the Tropical grasslands are made up of the Guinea, High, Dry and Sahel savannas. These regional differences are mainly due to variation in annual rainfall (which decreases from the coast northwards), the relief and the nature of the

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Table 1: Regions of collection of samples

| Sample | Area | Region | Village of Collection |
|---|---|---|---|
| *Cucumeropsis mannii* | High Savanna | North West | Bali |
| | High Savanna | West | Bantoum |
| | High Savanna | Adamawa | Ngaoundale |
| | Rain Forest | South | Ebolowa |
| | Rain Forest | East | Abong-Mbang |
| | Swamp Forest | South West | Muea |
| *Cucurbita maxima* | High Savanna | North West | Santa |
| | High Savanna | West | Galim |
| | Rain Forest/Guinea S. | Centre | Yambassa |
| *Cucurbita moschata* | High Savanna | North West | Mankon |
| | High Savanna | West | Bafounda |
| | Rain Forest/Guinea S. | Centre | Yambassa |
| | Swamp Forest | South West | Muea |
| *Lagenaria siceraria* | Dry Savanna | Far North | Yagoua |
| | High Savanna | North West | Zhoa |
| | High Savanna | West | Bafoussam |
| | Swamp Forest | Littoral | Douala |
| *Cucumis sativus* | High Savanna | West | Bazou |
| | High Savanna | Adamawa | Tignere |
| | Rain Forest/Guinea S. | Centre | Bafia |
| | Swamp Forest | South West | Muyuka |
| | Swamp Forest | Littoral | Japoma |

S. = Savanna (The Centre region has both Rain Forest and Guinea Savanna areas)

soil, which determine the drainage of the area. There is no clear cut division between the vegetations, as one area gradually gives way to another. The coastal lowland is covered by various sedimentary rocks, while the Cameroon highlands largely consist of basalt and granite, which are igneous rocks (Ngwa, 1978). The seeds were collected from regions of great production in the Swamp and Rain forests, Guinea, High and Dry savanna areas.

The Swamp forest is the coastal lowland area. It is characterized by heavy rainfall (300-400 cm), high humidity, slow drainage, swamps, estuaries, many creeks and dense forests. This area is nearer to the sea and the influence of the south-westerly monsoon winds (warm wet winds which blow from across the Atlantic Ocean) is felt for a longer period leading to occasional rainfall during the dry season. As the rain-bearing winds rise above Mount Cameroon, its moisture condenses and falls as relief rain. This region contains mainly sedimentary rocks (Ngwa, 1978). High nutrient reserves are found in the South West due to the volcanic influence (Moukam and Ngakanou, 1997). Regions of collection here were parts of the South West and Littoral Regions.

The Rain forest area lies inland from the Swamp forest. Red ferrallitic soil dominates most of the area. The vegetation is dense and luxuriant with tall trees struggling for sunlight in some parts. The rainfall is about 157 cm. The rain steadily reduces inland as the rain-bearing winds lose most of their moisture when they pass over the land. The climate is humid with equatorial heat (Guinea type climate) (Ngwa, 1978). This gives the region high humidity and precipitation. Average temperatures range from 24-26°C. Areas of collection here were parts of the South and East regions.

The Guinea savanna area lies after the Rain forest area. During the rainy season, it has scattered tree growth and tall grass ranging from 4 m in the South to 1.5 m in the North (Ngwa, 1978). The area was once a Rain forest, but exploitation of trees has allowed dense undergrowth to appear. The trees are both evergreen and deciduous. It has red ferralitic soils containing large deposits of raw minerals and several soil types towards the north (Bafia). The climate is the Guinea type. Precipitation is reduced and temperatures are 23°C (Wikipedia, 2009). The area of collection here was part of the Centre region.

The High savanna area is further away from the sea (inland) and it receives less rain than the coastal belt. It has good drainage and lacks enough moisture to support the growth of large forest trees. It is covered with short grasses and occasional clumps of trees, often evergreen in character. In a few places, outcrops of hard rock with little or no subsoil prevent the growth of trees. Rainfall varies depending on the location of the area to the rain-bearing winds. The average annual rainfall is 258 cm in Bamenda, which decreases to 150 cm in Ngaoundere. Bamenda (further from the sea) has more rain than Kumba (closer to the sea and located in the rain shadow of Mount Cameroon) because the Bamenda highlands force the southwest winds upwards, causing cooling and condensation of their high water vapour content. Parts of this area contain ancient volcanoes, where volcanic lavas have weathered into rich black soils (Ngwa, 1978). Areas of collection here include parts of the North West, West and Adamawa regions.

The Dry savanna area lies towards the North of the country. As the rainfall decreases further North, the

grass too becomes much shorter and the trees are more scattered and generally small in size. Outcrops of hard rock are common. The savanna becomes poorer and poorer until it merges into semi-desert and finally into the Sahara desert. It is green and fresh only during the brief rains. The rainfall in Maroua is 88.3 cm. This area has recent sedimentary rocks covered with black soil which is mostly ferralitic or lateritic. There is also much sand and clay in this region (Ngwa, 1978). The area of collection here was part of the Far North region.

**Treatment of samples:** The decorticated seeds were bought from farmers in the various regions of cultivation already dried under local conditions by these farmers. They were transported in polyethylene bags to the laboratory, wiped with filter paper and dried in an Oven at 70°C to constant weight. They were ground in an electric grinder, put in airtight bottles and stored in the desiccator for analyses.

**Methods of analysis:** The oil content was determined by continuous reflux in a Soxhlet apparatus for 8 h using hexane as solvent (AOAC, 1980). All the oils are liquid at room temperature. The acid, saponification, iodine and peroxide indices of the isolated oils were determined by colorimetric methods (AFNOR, 1981). The Percentage of Impurity was calculated from the formula:

$$\text{Percentage of Impurity} = (\text{Acid index} / \text{Saponification index}) \times 100$$

The fatty acid composition of the oils was evaluated by Gas Liquid Chromatography of methyl esters of fatty acids prepared according to the method of Morrisson and Smith (1964) with the mixture $BF_3$/methanol. The methyl esters were separated on a capillary column (DB 225, J and W; l: 30 m; internal diameter: 0.32 mm; thickness of film: 0.25 µm; gas vector: hydrogen: 2 ml/min) according to the procedure described by Alasnier *et al.* (2000). Detected with the aid of a flame ionisation detector ( 250°C), the fatty acid methyl esters were identified by comparing their retention times to those of a standard mixture of fatty acids and the peak areas were integrated. The surface area of the peaks which was assimilated to triangles gave the fatty acid composition of the mixture injected (% in weight of methyl ester mixture) according to the formula:

X % of methyl ester = (Surface area of corresponding peaks/Surface area of total peaks) x 100.

Data was analyzed using the SPSS 9.0 software. Analysis of Variance (ANOVA) was used to find the correlation between the parameters measured and the regions of cultivation of the seeds. Also ANOVA and the Kruskal-Wallis tests were used to find differences between the indices and fatty acids of oils from the various species of seeds. The Student-Newman-Keuls (S-N-K) test was used to locate these differences. The tests were done at the 5% level of significance.

Each result is a mean of three replications per sample according to the region of cultivation. The average for each specie of seed from the different areas is given as Mean ± Standard Deviation (SD).

## RESULTS AND DISCUSSION

**The oil content:** The oil contents of these egusi seeds ranged from 44.85 (*C. mannii*) to 53.69% dry weight (*C. sativus*) (Table 2). The oil content of *C. sativus* was similar to that of *C. moschata* (50.81%) but significantly higher than those of the other seeds, which had similar values (Achu *et al.*, 2005). Analysis of variance revealed that the oil contents depended on the areas of cultivation of the seeds ($p<0.05$). Highest values in the various species were from the High savanna (*C. mannii* from Adamawa, 50.52; *C. maxima* from the North West, 51.61 and *C. sativus* from the West, 56.13%) and Swamp forest areas (*C. moschata* from the South West, 54.45; *L. siceraria* from the Littoral, 52.15 and *C. sativus* from the South West, 56.53%).

**The acid index:** The acid index of the samples ranged from 3.4 (*C. mannii*) to 10 mgKOH/g of oil (*L. siceraria*) (Table 2). The acid index of *L. siceraria* was significantly higher ($p<0.05$) than that of the other oils, which had similar acid levels, as revealed by the Student-Newman-Keuls (S-N-K) test. Oils usually contain small amounts of free fatty acids such that when exposed to the air, these fatty acids, which are responsible for the acidity and oxidability of oils, produce unpleasant odours. The acid index measures the amount of these free fatty acids in oil, which can be used as a measure of its quality. In refined vegetable oils, the lower the free fatty acid content the more stable the oil, the more acceptable the oil to the human palate (Codex Alimentarius, 1999).

This high acid index in *L. siceraria* was due to this sample from the High savanna (West region), with a value of 22.23 mgKOH/g of oil. However, *L. siceraria* generally has high acid indices, indicating that the acid index depends more on the specie than on the area of cultivation. The rural population prefers the other species of egusi seeds for consumption to those of *L. siceraria*. This is because the cork of *L. siceraria* seeds is very hard and makes it more difficult for the seeds to be decorticated. Usually, it is in the absence of the other species that *L. siceraria* seeds are consumed. In some parts of the country especially in the West region, *L. siceraria* seeds are considered to be very precious and so are only consumed by twins. Consequently, they are usually stored for long before consumption or at times these seeds are stored just for planting, for the fruit (calabash) is more useful to the rural population such as utensils, water jars and musical instruments. In addition, high acid values which result from high

Table 2: Parameters for oil quality

| Samples | Area | Region | *[1]Oil (Lipid) content (g/100g d.W.) | Acid Index (mgKOH/g of oil) | *Saponification Index (mg KOH/g of oil) |
|---|---|---|---|---|---|
| *C. mannii* | High Savanna | North West | 47.48$^{b}$ | 3.63 | 189.02$^{d}$ |
| | High Savanna | West | 40.76$^{cd}$ | 1.76 | 219.36$^{c}$ |
| | High Savanna | Adamawa | 50.52$^{a}$ | 5.03 | 241.62$^{b}$ |
| | Rain Forest | South | 40.33$^{d}$ | 2.69 | 191.33$^{d}$ |
| | Rain Forest | East | 41.77$^{c}$ | 4.56 | 288.83$^{a}$ |
| | Swamp Forest | South West | 48.26$^{b}$ | 2.71 | 239.43$^{b}$ |
| | - | - | 44.85±4.03$^{c}$ | 3.40±1.24$^{B}$ | 228.27±37.30 |
| *C. maxima* | High Savanna | North West | 51.61$^{a}$ | 8.25 | 186.97$^{b}$ |
| | High Savanna | West | 49.79$^{b}$ | 5.46 | 236.06$^{a}$ |
| | Rain Forest/G.S | Centre | 45.72$^{c}$ | 2.23 | 191.63$^{b}$ |
| | - | - | 49.05±2.48$^{B}$ | 5.31±3.01$^{B}$ | 204.89±27.10 |
| *C. moschata* | High Savanna | North West | 53.85$^{b}$ | 4.98 | 176.01$^{c}$ |
| | High Savanna | West | 53.06$^{c}$ | 1.77 | 237.24$^{a}$ |
| | Rain Forest/G.S | Centre | 41.90$^{d}$ | 7.81 | 243.59$^{a}$ |
| | Swamp Forest | South West | 54.45$^{a}$ | 2.69 | 201.02$^{b}$ |
| | - | - | 50.81±5.17$^{AB}$ | 4.31±2.69$^{B}$ | 214.47±31.76 |
| *L. siceraria* | Dry Savanna | Far North | 49.01$^{b}$ | 9.13$^{b}$ | 216$^{c}$ |
| | High Savanna | North West | 49.87$^{b}$ | 4.57$^{b}$ | 177.99$^{d}$ |
| | High Savanna | West | 49.31$^{b}$ | 22.23$^{a}$ | 228.86$^{b}$ |
| | Swamp Forest | Littoral | 52.15$^{a}$ | 4.89$^{b}$ | 242.82$^{a}$ |
| | - | - | 50.08±1.23$^{B}$ | 10.21± 8.28$^{A}$ | 216.42±27.86 |
| *C. sativus* | High Savanna | West | 56.13$^{a}$ | 2.71 | 174.74$^{e}$ |
| | High Savanna | Adamawa | 49.15$^{c}$ | 4.55 | 214.69$^{d}$ |
| | Rain Forest/G.S | Centre | 53.83$^{b}$ | 1.76 | 230.18$^{c}$ |
| | Swamp Forest | South West | 56.53$^{a}$ | 1.77 | 286.0$^{a}$ |
| | Swamp Forest | Littoral | 53.14$^{b}$ | 7.77 | 250.78$^{b}$ |
| | - | - | 53.69±2.64$^{A}$ | 3.71±2.54$^{B}$ | 231.28±41.38 |

| Samples | Area | Region | *Iodine Index (g/100g of oil) | *Peroxide Index (meq/kg of oil) | Percentage of Impurity (%) |
|---|---|---|---|---|---|
| *C. mannii* | High Savanna | North West | 108.85 | 2.07$^{f}$ | 1.92 |
| | High Savanna | West | 102.11 | 10.51$^{b}$ | 0.8 |
| | High Savanna | Adamawa | 101.40 | 9.23$^{c}$ | 2.08 |
| | Rain Forest | South | 107.65 | 8.08$^{d}$ | 1.41 |
| | Rain Forest | East | 106.78 | 13.68$^{a}$ | 1.58 |
| | Swamp Forest | South West | 105.50 | 7.33$^{e}$ | 1.13 |
| | - | - | 105.38±3.02$^{A}$ | 8.48±3.85$^{B}$ | 1.49±0.48$^{B}$ |
| *C. maxima* | High Savanna | North West | 113.54$^{a}$ | 9.72$^{a}$ | 4.41 |
| | High Savanna | West | 106.84$^{b}$ | 6.58$^{b}$ | 2.31 |
| | Rain Forest/G.S | 191.63$^{b}$ | 81.47$^{c}$ | 5.86$^{c}$ | 1.16 |
| | - | - | 100.62±16.92$^{A}$ | 7.39 ±2.05$^{B}$ | 2.63±1.65$^{B}$ |
| *C. moschata* | High Savanna | North West | 78.01$^{c}$ | 31.95$^{a}$ | 2.83 |
| | High Savanna | West | 66.62$^{d}$ | 16.89$^{c}$ | 0.75 |
| | Rain Forest/G.S | Centre | 87.82$^{b}$ | 5.48$^{d}$ | 3.21 |
| | Swamp Forest | South West | 103.53$^{a}$ | 27.56$^{b}$ | 1.34 |
| | - | - | 83.81±15.59$^{B}$ | 20.47±11.83$^{A}$ | 2.03±1.18$^{B}$ |
| *L. siceraria* | Dry Savanna | Far North | 125.33$^{a}$ | 1.41$^{d}$ | 4.23$^{b}$ |
| | High Savanna | North West | 123.74$^{a}$ | 4.24$^{b}$ | 2.57$^{b}$ |
| | High Savanna | West | 76.08$^{c}$ | 3.17$^{c}$ | 9.71$^{a}$ |
| | Swamp Forest | Littoral | 117.29$^{b}$ | 5.30$^{a}$ | 2.01$^{b}$ |
| | - | - | 110.61±23.28$^{A}$ | 3.53±1.66$^{B}$ | 4.63±3.51$^{A}$ |
| *C. sativus* | High Savanna | West | 118.58$^{ab}$ | 7.67$^{c}$ | 1.55 |
| | High Savanna | Adamawa | 111.24$^{b}$ | 9.12$^{b}$ | 2.12 |
| | Rain Forest/G.S | Centre | 114.40$^{ab}$ | 3.31$^{e}$ | 0.76 |
| | Swamp Forest | South West | 102.37$^{c}$ | 14.11$^{a}$ | 0.62 |
| | Swamp Forest | Littoral | 124.81$^{a}$ | 5.97$^{d}$ | 3.1 |
| | - | - | 114.28±8.37$^{A}$ | 8.04±4.02$^{B}$ | 1.63±1.02$^{B}$ |

amounts of free fatty acids in oils may be due to the method of processing of the seeds: For some of the seeds, the fruits are opened and left overnight or for 2-3 days for the pulp to slightly ferment before the seeds are extracted from the fruit. This is in order to reduce the sticky and slimy nature of the content of the fruits for easy washing of the seeds. Fermentation favours the action of lipolytic enzymes, which hydrolyze triglycerides in the seeds, liberating free fatty acids. After washing the seeds are dried under the sun. If the sun is not hot enough, this drying can take a number of days before the seeds are completely dried. This slow drying causes the seeds to remain damp leading to slow fermentation. Hence, the conditions, duration of storage and drying of

the seeds and the hot extraction of the oils, can increase the acid index. This was also shown in the extraction of *Butyrospermum parkii* (Shea) butter, that acid index increases with temperature (Djeumako *et al*., 2000). These values were similar to those of *Canarium schweinfurthii* (4-10.01, Kapchie *et al*., 2000) and *(Ricinodendron heudelotii* (njansan) oils (2-9.24 mgKOH/g of oil, Aboubakar *et al*., 2000). The maximum acid index of edible oils is 15 mg KOH/g of oil (Krishnamurthy, 1982). Most of the acid values for these egusi oils were below this level, hence these oils can be considered as good edible oils.

**The saponification index:** The saponification index was from 204 (*C. maxima*) to 231 mg KOH/g of oil (*C. sativus*) (Table 2). The saponification index indicates the average molecular complexity of the molecule (Hilditch, 1947). It depends on the neutralization of the free fatty acids in oil and complete saponification of the fatty material (Meara, 1955). There was no significant difference between the mean saponification levels of these oils as shown by Analysis of Variance. However, the saponification indices were much higher in some samples from the Rain forest, East (*C. mannii*, 288.83) and Swamp forest (*C. sativus*, 250-286 mg KOH/g of oil). These values were slightly higher than those of *C. sativus* (191-197) and *Cucumis melo* (melon seed) oils (193) (Capelle, 1949); oils from *Zea mays*, corn (187-195); *Gossypium hirsutum*, cottonseed (189-198); *Sesamum indicum*, (sesame) and *Glycine max* (soybean) (189-195); *Helianthus annuus*, sunflower (188-194); *Arachis hypogaea*, peanut (187-196); *Elais guineensis*, palm (190-209) (*Codex Alimentarius*, 1999) and *Olea europaea*, olive oils (190-192 mg KOH/g of oil) (Capelle, 1949). They were lower than those of oils rich in Saturated Fatty Acids (SFA) such as *Cocos nucifera*, coconut (248-265) and *Elais guineensis*, palm kernel oils (230-254 mg KOH/g of oil) (*Codex Alimentarius*, 1999). These values were also slightly higher than those of non-conventional oils such as *Dacryodes edulis*, the African pear (201.4) (Omoti and Okiy, 1987), *Coula edulis* (180-185) (Tchiégang *et al*., 1998), *C. schweinfurthii* (177-197.79) (Kapchie *et al*., 2000) and *R. heudelotii* oils (181-198.02 mgKOH/g of oil) (Aboubakar *et al*., 2000).

**The iodine index:** The iodine index of the oils ranged from 83 (*C. moschata*) to 114 g/100 g of oil (*C. sativus*) (Table 2). The iodine index is a characteristic of the unsaturation of a fatty acid or its esters. Lipids with unsaturated fatty acids (containing one or more double bonds) are easily assimilated and broken down to produce calorific energy than saturated fatty acids. The degree of unsaturation of lipids can therefore be estimated by determining the iodine index, for these lipids quantitatively add iodine and the quantity of halogen absorbed represents a measure of the average unsaturation of the lipid. One molecule of iodine is bound to a double bond. The higher the iodine index, the more unsaturated the oil. However, when the iodine index becomes too high, the stability of the oil reduces because it is more likely to undergo oxidation. Higher values were found in *L. siceraria* (High and Dry savannas, 123-125.33 and Swamp forest areas, 117.29%) and *C. sativus* (High savanna, West, 118.58 and Swamp forest, Littoral, 124.81%) as revealed by the S-N-K- test. However, the mean iodine index of *C. moschata* was significantly lower ($p<0.05$) than that of the other seeds, which had similar iodine levels, as shown by the S-N-K- test. The iodine values were similar to those of *C. sativus* (115-118%) and *Cucumis melo* (101) (Capelle, 1949) and to those of unsaturated fatty acid-rich oils such as peanut (86-107), cottonseed (100-123), sesame (104-120), sunflower (118-141), but lower than that of *Glycine max*, soybean oil (124-139%). This high iodine index in soybean oil is probably due to its high level of linolenic acid (4.5-11%) (*Codex Alimentarius*, 1999). They were higher than those of saturated fatty acid-rich oils such as *Theobroma cacao*, cocoa butter (32-42) (Capelle, 1949), coconut (6-10.6), palm (50-55), palm kernel (14-21) (*Codex Alimentarius*, 1999) and *C. edulis* oils (90-95) (Tchiégang *et al*., 1998); but lower than those of *C. schweinfurthii* (116-152.8%) (Kapchie *et al*., 2000) and *Ricinodendron heudelotii* oils (140-169.77) (Aboubakar *et al*., 2000). The iodine index, which indicates the level of unsaturation in oils, shows that these oils have higher levels of polyunsaturated fatty acids, hence can be considered as semi- siccative liquid oils (have more linoleic followed by oleic acids, with an iodine index of 100-140 such as corn, cotton, sesame and sunflower seed oils). These oils can be used for consumption and in soap making, for oleic and linoleic acids favour the formation of foam and give a good detergent ability (Hilditch, 1947).

**The peroxide index:** The peroxide index of our samples ranged from 3 (*L. siceraria*) to 8 meq/kg of oil (*C. mannii*) except *C. moschata* (20 meq/kg of oil) (Table 2). The peroxide index is an indication of the amount of hydroperoxides present in oil. These compounds arise from lipid oxidation. The lower the peroxide value, the better the quality of the oil. Hence, the peroxide value is a measure of oil quality (*Codex Alimentarius*, 1999). The peroxide value was highest in *C. mannii* from the Rain forest, East (13.68), *C. moschata* from the High savanna (16-31.95) and Swamp forest, South West (27.56) and *C. sativus* from the Swamp forest, South West (14.11 meq/kg of oil), as revealed by the S-N-K- test. However, the mean peroxide index was generally higher in *C. moschata* ($p<0.05$) than that of the other oils, which had similar peroxide levels. *C. moschata* seeds are very small in size and not very easy to decorticate, hence are

usually eaten only in the absence of the other seeds or when there is famine in the village. These seeds also have a slightly bitter taste that is not very appreciated by most consumers who prefer to cultivate this specie for its delicious fruit, the melon. Consequently, these seeds are often stored for long after harvest before consumption, which may lead to a rise in its peroxide values. The peroxide value also depends on the method of preservation of the seeds (for the seeds were bought from farmers) and oils (the oils were stored at +4°C for about a month before analyses), the state of oxygenation (quantity of oxygen consumed), the method of oil extraction used and the type of fatty acids present in the oil. The high peroxide value in some of these oils may be due to much exposure of the seeds to the sun during drying, causing lipid oxidation resulting from the absorption of oxygen, which increases the formation of peroxides. Secondly, it can be due to heating of the oil during its extraction. Heat favours oxidation of fatty acids increasing the formation of peroxides (Cheftel and Cheftel, 1992). Thirdly, these oils contain mostly polyunsaturated fatty acids which could easily undergo oxidation, raising peroxide values in these oils. The peroxide values were lower than those of *R. heudelotii* oils (19-114) (Aboubakar *et al*., 2000). Most of our values were lower than 15 meq/kg of oil (the maximum level for cold pressed and virgin oils, *Codex Alimentarius*, 1999), showing that these oils are good edible oils.

**The percentage of impurity:** The percentage of impurity (acid/saponification index) ranged from 1.49 (*C. mannii*) to 4.63 (*L. siceraria*). This parameter was generally not influenced by the area of cultivation except that of *L. siceraria* which was significantly higher than that of the other seeds due to that of *L. siceraria* from the West which had a high acid value as revealed by the S-N-K- test. The higher the acid index, the higher the percentage of impurity, the lesser the stability of the oil. However, these oils were extracted under heat and analyzed for quality without refining. The high percentage of impurity (high amounts of free fatty acids) in some of these oils may be due to the methods of processing, the conditions and duration of storage of these seeds and oils and the method of extraction used in the laboratory.

**The fatty acid composition:** The fatty acid composition of the oils shows the presence of four main fatty acids: Palmitic, C16:0 (10-19%); stearic, C18:0 (7-11%); oleic, C18:1 (9-25%) and linoleic, C18:2 (49-69%) acids, amounting to 96-99% of the total fatty acids (Table 3). Linoleic was > oleic > stearic acid in all the samples, irrespective of the area of cultivation. Palmitic was also > stearic acid in all the samples except *C. sativus* with similar levels of these 2 fatty acids. Some of these values were influenced by their area of cultivation.

**Palmitic acid (C16:0):** The level of C16:0 in *C. moschata* was similar to that of *C. mannii*, but significantly higher ($p<0.05$) than that of the other seeds, which had similar levels, as revealed by the S-N-K- test. The C16:0 level was highest in *C. mannii* from the Rain forest, East (24.4). This sample also had some amount of C14:0 (4.7%) and C12:0 (1.5%), which were found only in traces in some species and inexistent in others. The C16:0 level was also highest in *C. moschata* from the High savanna, North West (22.2%). C16:0 is a saturated fatty acid which does not raise blood cholesterol levels when it is esterified in the alpha-position on triglycerides (as in palm oil). It is more hypercholesterolaemic, when it is esterified in the beta-position (as in butter fat) according to Keys and Hegsted in Ng (1994). The *C. mannii* and *C. moschata* from these two areas also had higher peroxide levels. The soils of these areas are rich in iron. The East region is characterised by metamorphic rocks and granite, wet equatorial climate with high temperatures (24°C), high humidity and precipitation (150-200 cm/year) and leaching caused by the humid environment, while the High savanna area is characterised by soils with deposits of crystalline rocks (granite and gneiss), basalt towards the northwest, cool equatorial climate with temperatures of about 22°C (Wikipedia, 2009). These may have contributed to this difference in values in *C. mannii* and *C. moschata*. The C16:0 level in the other species was not affected by the area of cultivation.

**Stearic acid (C18:0):** The C18:0 level in *C. mannii* (11.3) was similar to that of *C. sativus* (11%), but significantly higher ($p<0.05$) than that of the other seeds, as revealed by the S-N-K- test. The highest value was found in *C. sativus* from the High savanna, Adamawa (13.2%). This sample was also found to have the lowest oil content (49.15%) amongst this same specie collected from different areas. The Adamawa region is one of Cameroon's most geologically diverse areas. The soils are mostly made up of brownish-red laterites, the result of the annual shift between dry and wet conditions and soil wash on the mountains. The iron and aluminium content is high. Granite is found on the borders (East and West of the region), which gives way to crystalline and metamorphic rocks (mica, schists and gneiss) which are often covered by volcanic basalt. Volcanic rocks occur in the northeast and northwest of the region which also has ferruginous soil. The region's high elevation lends it a relatively cool climate average between 22-25°C, which consists of the equatorial type (South Cameroon) and the tropical climate (Adamawa plateaus). Rainfall is within 150-200 cm with a long dry period followed by a long wet period (Wikipedia, 2009). However, it is not well known whether this geological and climatic diversity of the various regions is responsible for these differences in values.

Table 3: Fatty acid composition (% of methyl fatty acids)

| Sample | Area | Region | °C12: 0 | °C14: 0 | C16: 0 | °C16: 1 | C18: 0 | C18: 1 | C18: 2 | C18: 3 |
|---|---|---|---|---|---|---|---|---|---|---|
| *C. mannii* | High S. | North West | 0.2 | 0.1 | 15.5 | 0.1 | 11.3 | 11.8 | 60.1 | 0.2 |
| | High S. | West | - | 0.2 | 15.3 | 0.1 | 12.2 | 14.4 | 56.9 | 0.2 |
| | High S. | Adamawa | - | - | 16.7 | - | 11.2 | 12.3 | 59.1 | 0.2 |
| | Rain F. | South | - | - | 17.6 | - | 10.8 | 9.6 | 61.0 | 0.2 |
| | Rain F. | East | 1.5 | 4.7 | 24.4 | 0.8 | 11.2 | 14.6 | 42.0 | 0.3 |
| | Swamp F. | South West | - | - | 17.3 | 0.1 | 11.4 | 18.3 | 52.0 | 0.2 |
| | - | - | 0.3± 0.6 | 0.8±1.9 | 17.8 ±3.4$^{a}$ | 0.2±0.3 | 11.3±0.5$^{a}$ | 13.5 ±3$^{bc}$ | 55.2±7.2$^{bc}$ | 0.2±0.04$^{ab}$ |
| *C. maxima* | High S. | North West | - | 0.2 | 13.3 | 0.1 | 9.3 | 16.0 | 60.0 | 0.2 |
| | High S. | West | - | 0.1 | 12.5 | 0.1 | 8.0 | 27.2 | 51.0 | 0.2 |
| | Rain F./G.S | Centre | - | - | 12.2 | - | 8.3 | 32.6 | 46.3 | 0.2 |
| | | | - | 0.1±0.1 | 12.6±0.5$^{b}$ | 0.1 ±0.05 | 8.5±0.5$^{b}$ | 25.3±6.9$^{a}$ | 52.4±5.7$^{bc}$ | 0.2$^{ab}$ |
| *C.moschata* | High S. | North West | - | 1.4 | 22.2 | 0.3 | 8.0 | 22.7 | 44.4 | 0.3 |
| | High S. | West | - | - | 15 | 0.1 | 8.3 | 19.1 | 56.5 | 0.3 |
| | Rain F./G.S | Centre | - | - | 19.2 | - | 8.7 | 18.7 | 47.7 | 0.2 |
| | Swamp F. | South West | - | - | 20.4 | - | 11.9 | 17.7 | 49.2 | - |
| | - | - | - | 0.3±0.6$^{a}$ | 19.2±2.6 | 0.1±0.1 | 9.2±1.6$^{b}$ | 19.6±1.9$^{b}$ | 49.5±4.4$^{c}$ | 0.2±0.1$^{a}$ |
| *L.siceraria* | Dry S. | Far North | - | 0.1 | 12.1 | - | 9.1 | 11.3 | 67.0 | - |
| | High S. | North West | - | - | 13 | 0.1 | 7.0 | 9.0 | 70.0 | 0.1 |
| | High S. | West | 0.5 | - | 13 | 0.1 | 7.0 | 8.4 | 70.0 | 0.2 |
| | Swamp F. | Littoral | - | - | 14 | - | 8.5 | 7.2 | 69.4 | 0.1 |
| | - | - | 0.1±0.2 | 0.02±0.05 | 13±0.8$^{b}$ | 0.1±0.06 | 7.9±1.1$^{b}$ | 9.0±1.7$^{c}$ | 69.1±1.4$^{a}$ | 0.1±0.1$^{b}$ |
| *C. sativus* | High S. | West | - | - | 10.9 | - | 9.4 | 14.1 | 64.8 | - |
| | High S. | Adamawa | - | - | 10.2 | - | 13.2 | 15.3 | 60.1 | 0.1 |
| | Rain F./G.S | Centre | - | - | 10.7 | - | 10.6 | 16.2 | 61.7 | 0.1 |
| | Swamp F. | South West | - | - | 11.8 | - | 12 | 17.5 | 57.7 | 0.2 |
| | Swamp F. | Littoral | | | 10.1 | - | 9.7 | 15.7 | 63.7 | 0.1 |
| | - | - | - | - | 10.7±0.6$^{b}$ | - | 11±1.4$^{a}$ | 15.7±1.1$^{b}$ | 61.6±2.5 $^{ab}$ | 0.1±0.1$^{b}$ |

| Sample | Area | Region | C20: 0 | C20: 4 | C22: 0 | SFA | MUFA | PUFA | °UnSFA | °$R_1$ |
|---|---|---|---|---|---|---|---|---|---|---|
| *C. mannii* | High S. | North West | 0.3 | 0.4 | - | 27.4 | 11.9 | 60.9 | 72.6 | 0.38 |
| | High S. | West | 0.3 | 0.4 | - | 28 | 14.5 | 57.5 | 72.0 | 0.39 |
| | High S. | Adamawa | - | 0.5 | - | 27.9 | 12.3 | 59.8 | 72.1 | 0.39 |
| | Rain F. | South | 0.4 | 0.4 | - | 28.9 | 9.6 | 61.6 | 71.2 | 0.40 |
| | Rain F. | East | 0.2 | 0.3 | - | 42 | 15.4 | 42.0 | 58.0 | 0.72 |
| | Swamp F. | South West | 0.3 | 0.4 | - | 29.0 | 18.4 | 52.6 | 71.0 | 0.41 |
| | - | - | 0.3±0.1 | 0.4±0.1 | - | 30.5±5.7$^{a}$ | 13.7±3.1$^{bc}$ | 55.8±7.2$^{b}$ | 69.5±5.6 | 0.4±0.1 |
| *C. maxima* | High S. | North West | 0.5 | 0.4 | - | 23.3 | 16.1 | 60.6 | 76.7 | 0.30 |
| | High S. | West | 0.5 | 0.4 | - | 21.1 | 27.3 | 51.6 | 78.9 | 0.27 |
| | Rain F./G.S | Centre | 0.4 | - | - | 20.9 | 32.6 | 46.5 | 79.1 | 0.26 |
| | - | - | 0.5±0.05 | 0.3±0.2 | - | 21.7±1.1$^{b}$ | 25.3±6.9$^{a}$ | 52.9±5.8$^{b}$ | 78.3±1.1 | 0.3±0.02 |
| *C.moschata* | High S. | North West | 0.4 | 0.3 | - | 32 | 23.0 | 45.0 | 68 | 0.47 |
| | High S. | West | 0.4 | 0.3 | - | 23.7 | 19.2 | 57.1 | 76.3 | 0.31 |
| | Rain F./G.S | Centre | 5.5 | - | - | 33.4 | 18.7 | 47.9 | 66.6 | 0.50 |
| | Swamp F. | South West | 0.5 | 0.3 | - | 32.8 | 17.7 | 49.5 | 67.2 | 0.49 |
| | - | - | 1.7±2.2 | 0.2±0.1 | - | 30.4±3.9$^{a}$ | 19.7±2.0$^{b}$ | 49.9±4.5$^{b}$ | 69.6±3.9 | 0.4±0.1 |
| *L.siceraria* | Dry S. | Far North | 0.4 | - | - | 21.7 | 11.3 | 67.0 | 78.3 | 0.28 |
| | High S. | North West | 0.3 | 0.5 | - | 20.3 | 9.1 | 70.6 | 79.7 | 0.25 |
| | High S. | West | 0.3 | 0.5 | - | 20.8 | 8.5 | 70.7 | 79.2 | 0.26 |
| | Swamp F. | Littoral | 0.4 | 0.4 | - | 22.9 | 7.2 | 69.9 | 77.1 | 0.30 |
| | - | - | 0.35±0.1 | 0.35±0.2 | - | 21.4±1.1$^{b}$ | 9.0±1.7$^{c}$ | 69.6±1.7$^{a}$ | 78.6±1.1 | 0.3±0.02 |
| *C. sativus* | High S. | West | 0.3 | 0.5 | - | 20.6 | 14.1 | 65.3 | 79.4 | 0.26 |
| | High S. | Adamawa | 0.3 | 0.5 | 0.3 | 24.0 | 15.3 | 60.7 | 76.0 | 0.32 |
| | Rain F./G.S | Centre | 0.4 | 0.3 | - | 21.7 | 16.2 | 62.1 | 78.3 | 0.28 |
| | Swamp F. | South West | 0.4 | 0.4 | - | 24.2 | 17.5 | 58.3 | 75.8 | 0.32 |
| | Swamp F. | Littoral | 0.4 | 0.3 | - | 20.2 | 15.7 | 64.1 | 79.8 | 0.25 |
| | - | - | 0.4±0.05 | 0.4±0.1 | 0.1±0.1 | 22.1±1.7$^{b}$ | 15.7±1.1$^{b}$ | 62.1±2.5$^{ab}$ | 77.9±1.7 | 0.3±0.03 |

G = Guinea, S. = Savanna, F. = Forest, SFA = Saturated fatty acids, MUFA = Monounsaturated fatty acids, PUFA = Polyunsaturated fatty acids, UnSFA = Unsaturated fatty acids, $R_1$ = % SFA/ % UnSFA, - = not found, Kruskal-Wallis test: ° = There is no significant difference between means in the same column without letter superscript. S-N-K test: Means with different letter superscript within each column are statistically different ($p<0.05$)

**Oleic acid (C18:1):** The C18:1 level in *C. maxima* (25.3) was significantly higher, while that of *L. siceraria* (9%) was significantly lower ($p<0.05$) than that of the other seeds, as shown by the S-N-K- test. The C18:1 level was highest in *C. mannii* from the Swamp forest, South West (18.3), *C. maxima* from the High savanna, West (27.2) and Guinea savanna, Centre (32.6) and *C. moschata* from the High savanna, North West (22.7%). Oleic acid (C18:1) appears to be neutral with regards to low density lipoprotein, LDL ("bad" cholesterol) but modestly raises high density lipoprotein, HDL ("good" cholesterol) (FAO, 1994). These high levels of C18:1

also led to high levels of Monounsaturated Fatty Acids (MUFA) in these respective oils. MUFA have been shown to increase HDL and reduce LDL levels. This was seen in a study carried out by During *et al.* (2000) where rats fed with experimental cheeses containing mostly MUFA resulted in a significant reduction of LDL (31%) and a significant increase of HDL (11%).

**Linoleic acid (C18:2):** The C18:2 level in *L. siceraria* (69.1) was similar to that of *C. sativus* (61.6%). This gave higher levels of PUFA in *L. siceraria* (69.6), which was similar to that of *C. sativus* (62.1%), but significantly higher than those of the other oils, as revealed by the S-N-K- test. Lowest levels of C18:2 were found in *C. mannii* from the Rain forest, East (42%), for this sample had higher levels of C16:0 (24.4%), C14:0 (4.7%) and C12:0 (1.5%); *C. maxima* from the Guinea savanna, Centre (46.3%), for it had higher levels of C18:1 (32.6%); *C. moschata* from the High savanna, North West (44.4%), for it had higher levels of C18:1 (22.7%) and C16:0 (22.2%) and *C. sativus* from the Swamp forest, South West (57.7%), for it had higher levels of C18:1 (17.5%) and C16:0 (11.8%). This also led to lower levels of PUFA in these oils. Linoleic acid (a polyunsaturated fatty acid) moderately reduces serum cholesterol and LDL levels (FAO, 1994).

**All Saturated Fatty Acids (SFA):** The content in Saturated Fatty Acids (SFA) ranged from 21 (*L. siceraria* and *C. maxima*) to 30% (*C. mannii* and *C. moschata*), which was significantly higher ($p<0.05$) than that of the other seeds, which had similar levels, as shown by the S-N-K-test. The highest value of SFA was found in *C. mannii* from the Rain forest, East (42%) due to its high levels of C16:0 (24.4%), C14:0 (4.7%) and C12:0 (1.5%); *C. moschata* from the Guinea savanna, Centre (33.4%) due to its high level of arachidic acid, C20:0 (5.5%). The SFA such as C12:0, C14:0 and to a lesser extent, C16:0 elevate serum cholesterol and LDL levels. C18:0 does not elevate serum cholesterol or LDL levels, but its other health effects are yet undefined (FAO, 1994).

**All Unsaturated Fatty Acids (SFA):** The content in unsaturated fatty acids (unSFA) ranged from 69 (*C. mannii*) to 78.6% (*L. siceraria*) with no significant difference between these values as shown by the Kruskal-Wallis test. The high levels of unSFA in these oils was due to their high levels of linoleic acid. This showed that these oils are good sources of unSFA, mostly PUFA, with linoleic acid (an essential fatty acid) being the most abundant (49-69.1%). Linoleic acid is the most important essential fatty acid, for it must be got from food. This is because, during the synthesis of unsaturated fatty acids, oleic acid (C18:1) can easily be formed from stearic acid (C18:0). That is, the desaturation of stearyl-CoA to form oleyl-CoA occurs readily in the mammalian liver. On the other hand, the desaturation of oleyl-CoA which is supposed to form octadecadienoic acid (linoleic acid) is not possible. However, the desaturation of linoleic acid is possible with the formation of 2 products: alpha-linolenic acid (in plants) and gamma-linolenic acid (in animals). Gamma-linolenic acid, though found only in very small quantities in animal fats, is an intermediate in the formation of arachidonic acid (Ottaway and Apps, 1984). Linoleic acid is therefore an essential component of the diet. An adult needs 10 g/day. These egusi seeds are therefore good sources of linoleic acid. The linoleic acid level in these seeds was similar to that of egusi seeds from Niger (30-74%) (Silou *et al.*, 1999). These results show that these egusi oils are better than animal fats in their content of linoleic acid, while animal fats contain mostly oleic acid (27-43%, Zamora, 2005). Our results for melon seeds were also similar to those of previous studies on *Cucurbita pepo* seed oil which was found to contain mostly palmitic, stearic, oleic and linoleic acids, with linoleic acid as the most abundant (Murkovic *et al.*, 1996 and Younis *et al.*, 2000). These values were different from those of Idouraine *et al.* (1996) and Zdunczyk *et al.* (1999) who showed that *C. pepo* seeds contain oleic acid as the most abundant fatty acid. The linoleic acid content of these oils (especially *L. siceraria*) was similar to that of *Carthamus tinctorius*, safflower oil, which has one of the highest linoleic acid contents (70%) (*Codex Alimentarius*, 1999). Our values were also similar to those of corn, cottonseed, sunflower, soybean and sesame oils, (similar fatty acid profile to egusi seeds and linoleic acid as the most abundant). They were different from those of peanut and palm olein oils, (oleic acid is the most abundant) and palm and coconut oils (contain mostly unsaturated fatty acids, C16:0 and C12:0 respectively) (*Codex Alimentarius*, 1999). These values were somehow also similar to those of non-conventional oilseeds. *D. edulis* oil has palmitic, oleic and linoleic acids, amounting to 95% (Bezard *et al.*, 1991) and the African pulp oil (63.4% pulp) is also rich in these 3 fatty acids (Kapseu and Tchiégang, 1996). These egusi oils were very poor in linolenic acid (0.1-0.22%). Though linolenic acid is an omega-3 fatty acid with positive health effects, it easily oxidizes and it is undesirable in edible oils because of the off-flavours and potentially harmful oxidation products formed. Warner and Gupta (2003) showed that decrease in linolenic acid from 2-0.8% in oils, improved flavour quality and oxidative stability of fried foods. This shows that for oil to be very good for frying, its linolenic acid level should be less than 1%, as found in these egusi oils. These oils can therefore be used as frying oils. Looking at the composition of these seeds, the best oils to be considered as sources of essential fatty acids should be those with the lowest possible value of $R_1$ (oils with the highest levels of linoleic acids). $R_1$ is the ratio of

saturated fatty acids to that of unsaturated fatty acids. This $R_1$ ranges from 0.3 (*L. siceraria*) to 0.4 (*C. mannii*), showing that *L. siceraria* is the best source of essential fatty acid among these egusi oils. Therefore, considering the linolenic acid levels and $R_1$ values (from the lowest to the highest values of linolenic acid and $R_1$) of these oils, they can be classified in decreasing order of importance as follows:

*L. siceraria* > *C. sativus* > *C. maxima* > *C. moschata* > *C. mannii*.

**Conclusion and Recommendations:** This study showed that the oil content, saponification, iodine and peroxide indices of Cucurbitaceae (egusi) seed oils from Cameroon are influenced by their areas of cultivation while the acid index and percentage of impurity of the oils do not depend on the areas of cultivation (but on the specie), except *L. siceraria*. Their acid and peroxide levels are slightly high, due to the duration of drying, storage and the methods of processing of the seeds and oils; but these values are within recommended limits and could be excellent if these oils are refined. The saponification indices are slightly higher, while the iodine indices were closer to those of unsaturated fatty acid-rich oils (corn, cottonseed, sesame, sunflower and peanut oils), showing that they are rich in unsaturated fatty acids. These oils are very rich in essential fatty acids (linoleic acid) but poor in linolenic acid especially *L. siceraria*. Their fatty acid profile follows the same pattern as that of corn, cottonseed, soybean and sesame oils. The linolenic acid level of these egusi oils is much lower than that of soybean. The acceptable acid and peroxide values, high linoleic and low linolenic acid levels of these oils suggest that they could be sources of good edible oils such as table and cooking. The abundance of linoleic followed by oleic acid in these oils makes them good oils for reducing serum cholesterol and LDL and increasing HDL levels, hence could be good oils for the fight against cardiovascular illnesses. They can also be used to make mayonnaise and soap, for oleic and linoleic acids favour the formation of foam and give a good detergent ability. These oils have higher linoleic and lower linolenic acid levels than animal oils. This makes them less oxidizable, hence, good edible oils.

For further research, a detailed study will be conducted on the methods of handling of the fruits and seeds in the different villages and on the effects of the various methods of extraction on the quality and yield of the oil. Studies will also be conducted on the physical properties of these oils, the lipid composition and the atherogenicity of these oils *in vivo*.

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