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Physicochemical characterization of traditional Ghanaian cooking oils, derived from seeds of Egusi (*Citrullus colocynthis*) and Werewere (*Cucumeropsis manni*)

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ABSTRACT

Traditional vegetable oils derived from Egusi (*Citrullus colocynthis*) and Werewere (*Cucumeropsis manni*) could prove to be an important commodity for Ghanaians, serving as a potential alternative source of common cooking oils. This study measured several physicochemical properties of Egusi and Werewere oils to describe and assess their nutritional quality, susceptibility to rancidity, and potential industrial applications. Physicochemical measurements were also taken on olive oil and coconut oil for comparative analysis and method validation. The solvent extraction yield of oil from seed of Egusi (39.94%) and Werewere (28.82%) fares well against the yields of common cooking oil seeds. Refractive index and iodine value tests for Egusi (1.471, 122.94) and Werewere (1.470, 106.134) reveal that the oils are likely rich in unsaturated fats compared to olive and coconut oil. These measurements also suggest the traditional oils are susceptible to oxidative rancidity. Both Egusi and Werewere oils exceeded the FAO/WHO standards for permissible levels of impurity in edible oils. A high acid value (6.9) was measured for Egusi, suggesting the presence of free fatty acids. A high iodine value (122.9) was also measured for Egusi which suggests high unsaturation, likelihood to oxidation and susceptibility to rancidity. Overall, rigorous extraction and screening processes and additives may be required to produce Egusi and Werewere oils that are aligned with industry standards. The high extraction yield and prospective nutritional benefits of the oils are cause to explore further the use of these vegetable oils.

Keywords: Vegetable oil, physicochemical properties, unsaturated fats, nutritional quality

INTRODUCTION

African traditional vegetables have long been perceived as potentially useful for income generation and the promotion of food security (Achigan-Dako et al., 2012). It is imperative to study the diverse uses of traditional vegetables to further facilitate these prospective functionalities. *Citrullus colocynthis* and *Cucumeropsis manni*, of the Cucurbitaceae family, grow widely throughout much of West Africa. While commonly planted in cropping systems, these traditional vegetables are also harvested from rainforests, where they grow wildly. Both vegetables occupy important roles in many regional cultures, as West Africans have

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developed many culinary and medicinal uses for the plants (Duke, 1996; Egunjobi, 2004). In Ghana, *Citrullus colocynthis,* called Egusi, and *Cucumeropsis manni,* called Werewere, are generally harvested for their seeds. The cucurbit seeds are often ground to flour to enrich the consistency and flavor of stews (National Research Council, 2012). Seeds of both species and many other cucurbit vegetables are sold in major markets throughout most regions of Ghana (National Research Council, 2012) (Figure 1).

Seeds of both species are also used to make cooking oils. The use of Egusi and Werewere as cooking oils could prove to be an important economic asset for Ghanaians. Increased production could generate revenue and decrease the need for imported oils, contributing to the independence and prosperity of regional food systems. The traditional oils may also serve as a valuable export, as international demand for new vegetable oil sources has increased (Gohari et al., 2011). The oil sources may be attractive to consumers, as prior studies have described cucurbit-derived oils as having “favorable nutritional status,” due to their high levels of unsaturated fats (Sew et al. 2010). Before exploring the potential economic development of the traditional oils, it is important to first study their physical and chemical properties. This information can provide preliminary insight on the oils’ fat qualities, resistance to rancidity, and prospective industrial characteristics. This study aims to evaluate the physicochemical properties of both Egusi and Werewere oil to assess their suitability as alternatives to common cooking oils.

MATERIALS AND METHODS

Seeds of Egusi and Werewere were purchased from a local merchant at Kotokuraba Market in Cape Coast, Ghana. A bottle of coconut oil was acquired from the same merchant. A bottle of imported olive oil was purchased from Sonturk supermarket, also in Cape Coast, Ghana. All the samples were obtained in June 2012.

Oil extraction

The following procedure was performed, in separation, to extract the oil from the Egusi and Werewere seeds: The purchased seed was milled with a heavy duty blender. 150 grams of milled seed was extracted with petroleum ether (40-60°) using a soxhlet extractor on a water bath for 4 to 5 hours. The extracted oil was then concentrated under pressure. Both oil yields were placed into separate brown bottles in desiccators for further drying and storage.

Physicochemical properties

The following physicochemical parameters were measured for Egusi and Werewere oil, as well as olive oil and coconut oil for comparative analysis. The properties of olive oil and coconut oil were measured to ensure that results were generally concordant with established FAO/WHO standards for the oils as indicated in the literature (Nagre et al., 2011).

Specific gravity

The specific gravity of each oil was recorded as a general measure of oil density compared to the density of water (Nagre et al., 2011). This is useful for physically comparing and identifying oils. The specific gravity was determined using the specific gravity bottle method. The following formula was used to calculate the specific gravity of each oil:

$$\textit{Specific Gravity} = \frac{(\textit{weight of bottle} + \textit{oil}) - (\textit{weight of bottle})}{(\textit{weight of water})}$$

Refractive index

The refractive index was measured, as this figure can help determine the level of unsaturation of the fatty acids in oils, a nutritive quality of interest for this study (Nagre et al., 2011). A refractometer was used to measure the refractive index of each oil.

Viscosity

The dynamic viscosity of each oil was measured as an additional proxy for fat unsaturation, as prior studies have described an inverse relationship between viscosity and fatty acid unsaturation in oils (Abramovic 2012). Viscosity was determined at room temperature, using an Alpha Series rotational viscometer.

Saponification value

The saponification value of each oil was measured to explore the potential industrial uses for the oils, as this parameter reveals oil's suitability to be made into soap (Cuppett, 2001). Two grams (2 g) of oil was dissolved in 25 ml of alcoholic potassium hydroxide. The mixture was refluxed for 45 minutes and then cooled. 1 ml of phenolphthalein indicator was added. The solution was titrated using 0.5 M HCl. A blank determination was conducted. Saponification values were determined using the following formula:

$$Sap\ Value = 56.1N\ \frac{(V_2 - V_1)}{W}$$

N = Normality of HCl solution
V_2 = Volume (ml) of HCl used on blank
V_1 = Volume (ml) of HCl used on oil
W= Weight of oil sample (g)

Iodine Value

The iodine value of each oil was measured, as this value is also useful for determining the unsaturation level of the fatty acids in oil (Akinyeye et al., 2011). Approximately 0.2 grams of oil was placed into a 500 ml flask and dissolved in 15 ml of CCl_4 and 25 ml of Wijs solution. The flask was covered, swirled, and placed in the dark for 30 minutes. After which, 20 ml of 10%Kl solution and 150 ml of distilled water was added. Using 1.5 ml of starch indicator solution, the mixture was titrated with 0.1 N sodium thiosulphate solutions. A blank determination was conducted. Iodine values were calculated using the following formula:

$$IV = \frac{12.69\ (V^2 - V^1) \times N}{W}$$

W_2 = Weight of paper before filtering
W_1 = Weight of paper after filtering
W_3 = Weight of initial sample

N = Normality of $Na_2S_2O_3$ solution
V_2 = Volume (ml) of $Na_2S_2O_3$ used on blank
V_1 = Volume (ml) of $Na_2S_2O_3$ used on oil
W= Weight of oil sample (g)

Acid value

The acid value, an indirect measurement of free fatty acid levels, was recorded to test the oils' freshness and likeliness to develop taste and odor defects (Akinyeye et al., 2011; Nagre et al., 2011) Five grams (5 g) of oil was dissolved in a neutral solvent (25 ml diethyl ether + 25 ml 95% ethanol). The mixture was titrated with 0.1 N sodium hydroxide using 1 ml of phenolphthalein indicator solution. The acid value (in mg KOH / gram of oil) was calculated with the following formula:

$$AV = \frac{56.1\ N \times V}{W}$$

V = Volume (ml) of NaOH solution
N = Normality of NaOH solution
W= Weight of oil sample

Impurities

The level of impurities (mesocarp fibers, insoluble materials, phosphatines, trace metals, and oxidation products) was measured in each oil, as high levels of these substances are typically prohibited in the regulated production of edible oils (Watanapoon, 2004). Two grams (2 g) of oil was weighed into a 500 ml flask and mixed with 20 ml of a 1:1 solvent (petroleum ether and diethyl ether). The contents were vigorously shaken, covered, and allowed to stand for 24 hours. The mixture was filtered through a weighed 11 cm qualitative filter paper. The paper was then washed with 10 ml of the 1:1 solvent and placed in an oven at 103 ºC for one hour. The dried paper was then weighed. The impurity (%) of each oil was calculated with the following formula:

$$\boldsymbol{Impurity}\ (\%) = \frac{(\boldsymbol{W_2} - \boldsymbol{W_1})}{\boldsymbol{W_3}}$$

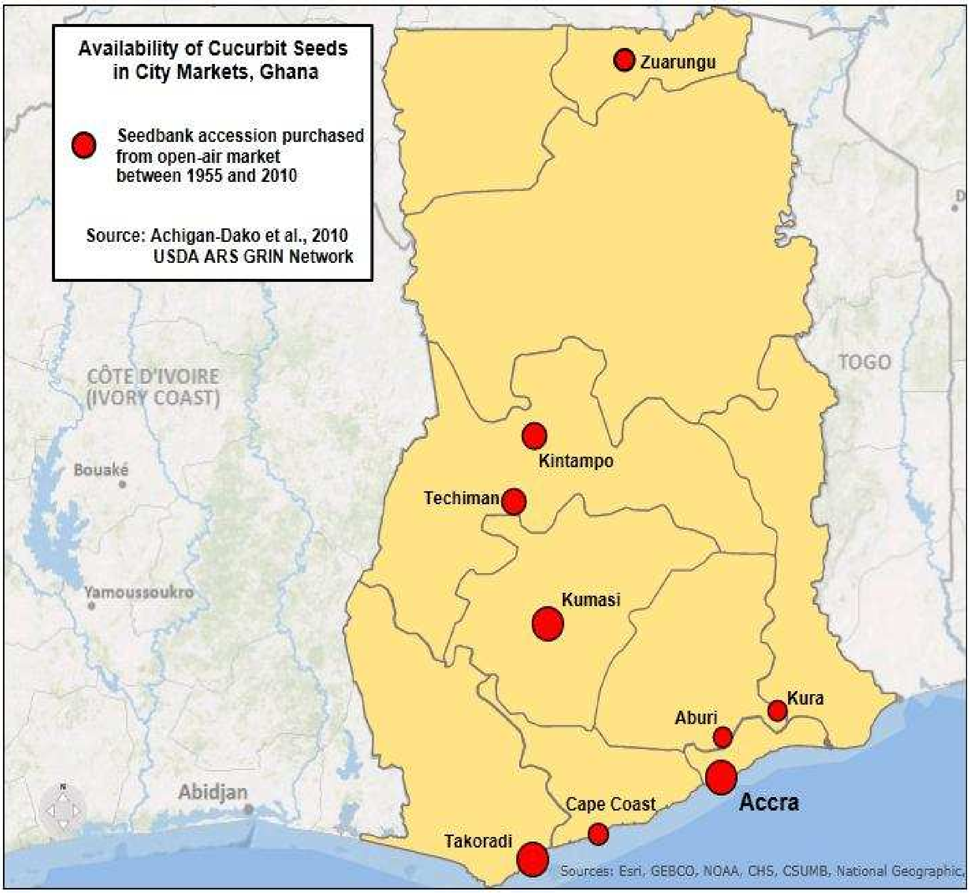


Figure 1: Depicted above are cities in Ghana where Cucurbitaceae seeds are sold in markets, as botanists (USDA ARS and Achigan-Dako, 2008) have acquired seed bank accessions of cucurbit species from these cities. The true distribution of cucurbit seed availability is likely more vast.

RESULTS

Oil extraction yield

The solvent extraction method produced a yield of 59.91 grams of concentrated Egusi oil (39.94%) and 43.23 grams of concentrated Werewere oil (28.82%).

Physicochemical properties

Table 1 details the results of the physicochemical property measurements on Egusi and Werewere. Table 1 also displays the results of the measurements obtained on olive oil and coconut oil, which were generally aligned with FAO/WHO Standards (Codex Alimentarius, 1992). Slight deviations from the standards on certain measurements, such as iodine value and impurity levels, could have resulted from poor storage conditions and/or contamination of the olive and coconut oils at the market prior to purchase. The Codex standards are not definitive requirements; some deviation is to be expected and no standard deviation is provided in the Codex.

Table 1: Results of the physicochemical property measurements and list of olive and coconut oil measurements compared to FAO/WHO standards.

	Egusi	Werewere	Olive	Coconut	Olive oil standard	Coconut oil standard
Solvent Extraction Yield (g)	59.91	43.23	X	X	X	X
Refractive Index	1.471	1.470	1.466	1.453	1.467 -1.4705	1.448 -1.450
Specific Gravity	0.91737	0.91616	0.9104	0.9226	0.910- 0.9106	0.90 - 0.92
Viscosity	24.5	21.1	31.8	32.1	X	X
Saponification Value	177.375	188.961	200.374	251.041	184-196	248- 265
Iodine Value	122.94	106.134	69.795	9.51	75- 94	6.3- 10.6
Acid Value	6.9	1.425	0.204	1.219	≤ 4.0	≤ 4.0
Impurity (%)	0.185	0.13	0.1	0.085	≤ 1.0	≤ 0.05

(Standards: Codex Alimentarius, 1992)

DISCUSSION

Oil extraction yield

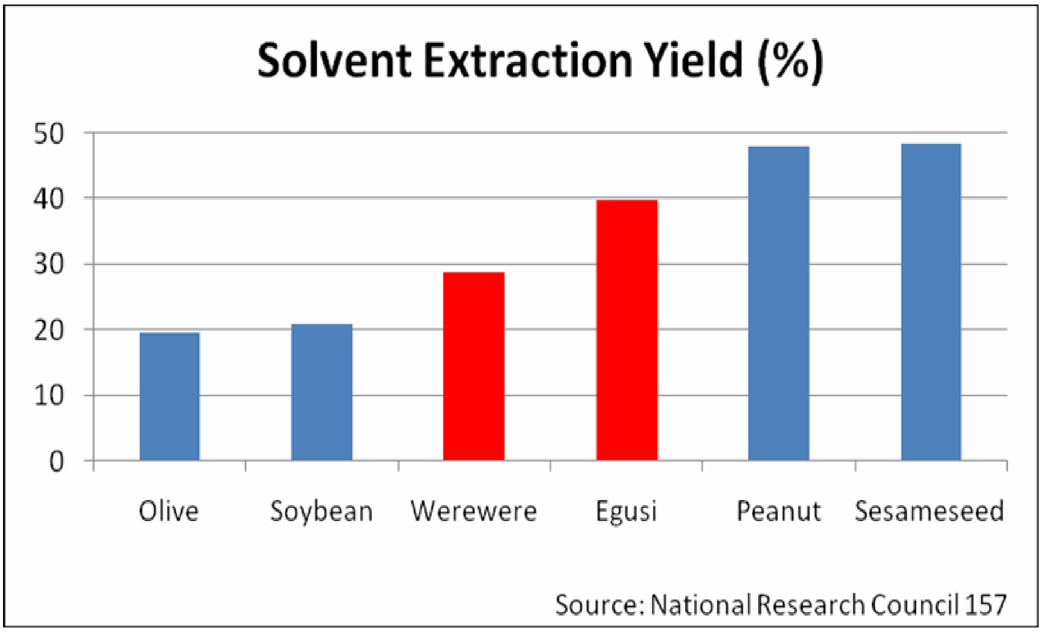
The relatively high yield of Egusi oil is concordant with the results of previous studies, suggesting that Egusi is capable of producing comparable levels of oil to peanuts (48%), under optimal extraction conditions. While less successful, the Werewere yield fared better than other oil crops, such as soybean, which produces an edible oil yield of approximately 18 percent (National Research Council, 2012). Figure 2 shows the yield of Egusi and Werewere compared to common cooking oil crops. This result is promising for the development of Egusi and Werewere as new vegetable oil sources; yield percentages are an important economic consideration to cooking oil manufacturers. The result may be useful for further studies to contribute data to common oil yield figures.

It is important to note that the seeds used in this experiment were unroasted; seeds analyzed in many studies are generally roasted before oil extractions. Roasting has been shown to yield more oil, likely by reducing the moisture content of the kernel and allowing for easier rupture of the cell walls. Badifu (1993) also noted that heating denatures protein, leading to the release of more oil from the kernel.

Physicochemical properties

The similar specific gravities of Egusi oil (0.91737) and Werewere oil (0.91616) are likely due to the common family of the two species. This indicates that seeds of both species produce oils that are similar in density. Both Egusi and Werewere oils were less dense than coconut oil (0.9226) and denser than olive oil (0.9104). These distinctions are important for volumetric considerations to be made by prospective oil manufacturers.

Refractive index and iodine value are both measurements of fatty acid unsaturation. Prior studies have noted a strong positive correlation between these measurements and fat unsaturation (Nagre et al., 2011; Ihediohanma et al., 2012). The refractive index and iodine value measurements for Egusi (1.471, 122.94) and Werewere (1.470, 106.34) indicate that the oils contain a high level of unsaturated fatty acids. As both measurements are intended to record the same nutritional quality of the oils, their correlation was tested; yielding an R^2 of 0.978 (Figure 3) .The agreements of both parameters indicates that the traditional oils are likely rich in unsaturated fats. The viscosities of Egusi (24.5 MPa) and Werewere (21.1 MPa) also suggest that the oils are richer in unsaturated fats than olive oil (31.8 MPa) and coconut oil



Source: National Research Council 157

Figure 2: Egusi and Werewere solvent extraction yields to compare to those of common oil crops.

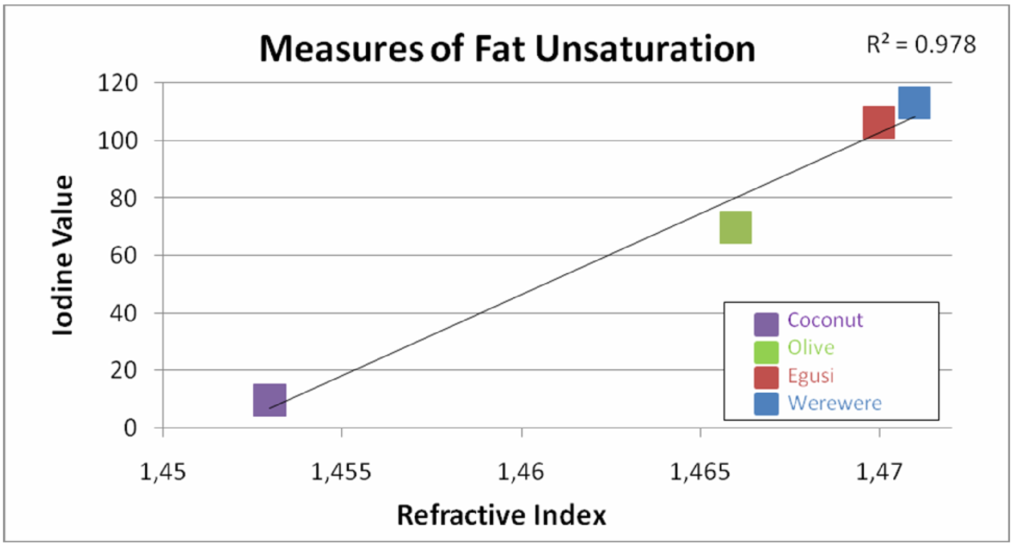


Figure 3: Correlation of fat unsaturation measurements indicates that Egusi and Werewere oils are likely rich in unsaturated fats. Coconut oil results confirm the relationship; this oil is known for high saturated fat levels.

(32.1 MPa), although the measurement was not significantly correlated with the other fat unsaturation parameters. The results of these three measurements are concordant with previous studies that describe high levels of fat unsaturation in cucurbit-derived oils. This result is promising for the nutritional prospects of these oils, as common dietary advice suggests the avoidance of saturated fats, which are known to contribute to cardiovascular diseases (Sew et al., 2010; Ihediohanma et al., 2012). However, the high iodine values (+100) of the traditional oils reveal that they are less stable to oxidation, and thus are more susceptible to rancidity (Akinyeye et al., 2011). This figure is important when considering the prospective shelf life of the traditional oils, as proper bottling and storage conditions must be developed to ensure their freshness; the addition of antioxidants could alleviate this problem. The saponification values of Egusi (177.375) and Werewere (188.961) reveal the average chain lengths, and thus the molecular weights, of the fatty acids in these oils. These figures will be useful for future studies of the fatty acid composition of the oils. For industrial purposes, the result suggests that Werewere, with a value in the range of most maize, sesame, and soybean oils (185-195), is likely more suitable for soap production than Egusi, which exhibited a value comparable to rapeseed oils (168-181) (Codex Alimentarius, 1992). The acid value measurement for Werewere (1.425) was comparable to that of coconut oil (1.219). This suggests that the two oils have comparable levels of free fatty acids. While the levels may be similar, the FFA composition of the oils may be different, rendering various health implications; future studies will address these possible differences. The acid value for Egusi (6.9) was much higher than the Codex Alimentarius standard (no more than 4.0). According to the Codex, oils exceeding this standard are "not suitable for human consumption", as high free fatty acid levels can contribute to an increased risk of oil rancidity, bitterness in flavor, and foulness in odor (Nagre et al, 2011; Cuppett, 2001). Some studies indicate that the prolonged consumption of high FFA products could pose cardiovascular health risks, such as increased blood pressure and risk of cardiac arrest (Kearney et al., 2012). While the analyzed sample yielded a high acid values, prior studies have found acid values as low as 3.0 in Egusi (National Research Council, 2012). Future studies should aim to assess potential variations in acid value based on sample storage conditions, oil extraction method, and geography.

The levels of impurity for Egusi (18.5%) and Werewere (13%) were both higher than the Codex standards for permissible levels of impurity for edible oils (no more than 5%). Before regulated production of these oils can progress, the impurity levels should be addressed. The seeds used for this study were likely subjected to unsterile, open-air market conditions prior to purchase; this may have impacted the impurity levels of the processed oils. Future studies will focus on extracting oils from thoroughly cleaned seeds in a heavily filtered environment.

Conclusions

This physicochemical study revealed both promises and impediments to the potential future regulated production of Egusi and Werewere as cooking oil alternatives. With high rates of oil extraction, cooking oil producers may want to examine Egusi and Werewere as potential product sources. The high levels of fat unsaturation in both oils provide the most promising revelation, suggesting a potential nutritional advantage over common cooking oils. Future studies can utilize the iodine values and saponification values yielded from this study to further characterize the composition of fatty acids in both traditional oils. A thorough fatty acid composition analysis will be required to make absolute inferences about the nutritional qualities of the oils. The high acid value of Egusi further suggests the oil's tendency towards rancidity. The high level of impurities in both traditional oils poses a level of risk in their consumption. These properties should be reexamined in future studies, using highly sanitized seed sources. It would also be useful for further studies to compare the effects of various oil extraction methods on these standard-exceeding properties. As the traditional oils are actively consumed in Ghana, future studies should consider measuring the physicochemical properties of oils extracted through traditional methods, as results may be of public health and nutritional relevance. Overall, this study provided a base of information on these oils. Future studies can utilize this information to thoroughly describe and analyze Egusi and Werewere oils, exploring their prospects as safe and marketable commodities.

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REFERENCES

Abramovic H, Klofutar C. 1998. The Temperature Dependence of Dynamic Viscosity for Some Vegetable Oils. *Acta Chimica Slovenica,* **45**(1): 69-77.

Achigan-Dako E, Fagbemissi R, Avohou H, Vodouhe R, Coulibaly O, Ahanchede A. 2008. Importance and practices of Egusi Crops in sociolinguistic areas in Benin. *Biotechnology, Agronomy, Society and Environment,* **12**(4): 393-403.

Akinyeye RO, Adeyeye EI, Fasakin O, Adedunke AA. 2011. Physicochemical Properties and Anti-nutritional Factors of Palm Fruit Products (Elaeis guineensis jacq.) from Ekiti State, Nigeria. *Electronic Journal of Environmental, Agricultural, and Food Chemistry,* **10**(5): 2190-2198.

Ardabili AGR, Farhoosh GR, Khodaparast. MH. 2011. Chemical Composition and Physicochemical Properties of Pumpkin Seeds Grown in Iran. *Journal of Agriculture, Science, and Technology,* **13**: 1053-1063.

Badifu GIO. 1993. Food potentials of some unconventional oil seeds grown in Nigeria: A brief review. *Plant Food Hum. Nutr.,* **43**: 211-224.

Codex Alimentarius. 1992. Fats, Oils, and Related Products. Food and Agriculture Organization of the United Nations N.p. UNIT D14 Oil Quality Indices

Cuppett SL. 2001. *Current Protocols in Food Analytical Chemistry*: John Wiley and Sons. Lincoln, NE.

Duke JA. 1996. *Citrullus Colocynthis Schrad. Centre for New Crops and Plant Products*. Purdue University.

Egunjobi JK, Adebisi AA. 2004. *Cucumeropsis mannii* Naudin In *Vegetables/ Légumes,* Grubben GJH, Denton OA (eds). PROTA 2: PROTA, Wageningen, Netherlands.

Gohari AA, Farhoosh R, Haddad KMH. 2011. Chemical composition and physicochemical properties of pumpkin seeds (*Cucurbita pepo* Var. Styriaka) grown in Iran. *J. Agr. Sci. Tech*. **13**: 1053-1063.

Ihediohanma NC, Ubbaonu, Akobundu E, Bungio E. 2006. Physicochemical properties of nigerian pumpkin seed oil. *Nigerian Food Journal*, **24**(1): 123-26.

Kearney MT, Chowizeinik PJ, Brett E, Sutcliff AS, Ritter J, Shaw AM. 2002. Acute Haemodynamic effects of lipolysisinduced increase of free fatty acids in healthy men. *Clinical Science,* **102**: 495-500.

Nagre RD, Oduro I, Ellis WO. 2011 Comparative Physico-chemical évaluation of Kombo Kernel fat produced by three different processes. *African Journal of Food Science and Technology*, **2**(4): 83-91.

National Research Council. 2012. *Egusi, Vegetables: Lost Crops of Africa* (Vol II). National Academies: Washington DC. 154-157

Sew CC, Nurul A, Zaini M, Farooq AF, Azizah A, Hamid AA, Saari N. 2010. Nutritional Composition and Oil Fatty Acids of Kundur Seed. *Pakistan Journal of Botany,* **42**(5): 3247-255.

Watanapoon S. 2004. Improvement of physicochemical properties of palm Oilein Blended with rice bran oil. PhD thesis. Silpakorn University. Thailand.