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INVESTIGATION OF PHYSIOCHEMICAL AND STORAGE CONDITIONS ON THE PROPERTIES OF EXTRACTED TIGER NUT OIL FROM DIFFERENT CULTIVARS

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ABSTRACT

Tiger nut oil was extracted from (black, brown and yellow) cultivars using n-hexane. Physiochemical properties (refractive index, specific gravity, acid value, free fatty acid, peroxide, saponification and iodine values of the oil samples were determined. Storage studies on the tiger nut oils were done by monitoring changes in the thiobarbituric acid, peroxide value, free fatty acid and moisture content for twelve (12) weeks. The refractive index, specific gravity, acid value and free fatty acid value ranged between 1.46‑1.47, 0.89‑ 0.90, 0.4‑ 1.40mg/g, and 0.20‑ 0.75% respectively. The peroxide, saponification and iodine values ranged between 3.99‑4.43meq/kg, 183.25‑202.87mg/kOH/g and 29.69‑31.74g/l2/g respectively. The major fatty acids (FAs) of the tiger nut oil were oleic (77.71%), palmitic (16.17%), and stearic (5.08%) acids for the black cultivar, oleic (64.12%), palmitic (11.86%), linoleic (11.87%) and dihum‑g‑linolenic (1.71%) for the brown cultivar while the yellow cultivar had oleic (68.89%), linoleic (12.77%), palmitic (13.33%) and stearic (4.46%). During storage peroxide value, free fatty acid, moisture content and thiobarbituric acid of the oil were within the maximum limits as recommended by CODEX Alimentarius.

Keywords: Tiger Nut Oil, Physiochemical Properties, Fatty Acid Profile, Cultivars, Storage

INTRODUCTION

Vegetable oils constitute an important part of the diet of humans. There is an increasing awareness of the importance of vegetable oils as source of health enhancing compounds. Thus the world demand for vegetable oil is set to rise even more rapidly from year to year, and this trend will impact on the price levels of oils. It is therefore important that countries and communities which have non-conventional seed oils carry out research that can lead to commercial production of their seed oils to at least satisfy local demand (**Olagunju, 2006**).

Tiger nut *(Cyperus esculentum)* is a perennial grass-like plant with spheroid tubers, pale yellow cream kernel surrounded by a fibrous sheath. It is also known as yellow nut sedge, earth or ground almonds, "*souchet"* in French, "*ermandeln"* in German and "*chufa"* in Spanish (**TTSL, 2005**). **Grossman and Thomas (1998)** reported that *chufa* came to Spain from Africa. Tiger nut is found wild and cultivated in Africa, South America, Europe and Asia. Tiger nuts grow in the wild, along rivers and are cultivated on a small scale by rural farmers mostly in the northern states of Nigeria. It is locally called "*aya*" in Hausa; "*aki awusa*" in Igbo; "*ofio*" in Yoruba and "*isipaccara*" in Effik (**Ndubuisi, 2009**). Tiger nuts are edible, sweet, nutty, flavored tubers which contain protein, carbohydrate, sugars, and lots of oil and fiber (FAO, 2000). Unfortunately, despite these potentials in tiger nuts it has been a neglected crop in Nigeria. This probably may be due to inadequate knowledge on its production, utilization and nutritional value. Tiger nut could provide a basis for rural industries in Africa. It is an important food crop for certain tribes in Africa, often collected and eaten raw, baked as a vegetable, roasted or dried and ground to flour. It is mostly consumed raw as snack without knowledge of the food and nutritional quality (**FAO, 1988**). It has also been found to possess good therapeutic quality (**Moore, 2004**). Various food processing techniques can be applied to tiger nut processing to modify its appearance, develop its natural flavor, stimulate the digestive juices, add cultivar to the menu, make it easily digestible and bio-available, destroy harmful microorganisms, improve its nutritional quality and prevent decomposition (**Ndubuisi, 2009**). There are mainly three varieties namely**:** black, brown and yellow, and only yellow and brown are readily available in the Nigerian markets. The yellow cultivar is preferred to all other varieties because of its inherent properties like its bigger size, attractive color and fleshier body. The yellow cultivar also yields more milk, contains lower fat and less anti-nutritional factors especially polyphenols (**Okafor *et al*., 2003).**

Tiger nut helps to prevent heart problems, thrombosis and activate blood circulation; it is also responsible for preventing and treating urinary tract and bacterial infection and assist in reducing the risk of colon cancer when eaten (**Adejuyitan *et al*., 2009**). The edible and stable oil obtained from the tuber is said to be superior oil that compares favorably with olive oil. The oil is golden brown in color and has a rich, nutty taste (**Bamishaiye *et al*., 2011**). The oil remains in a uniform liquid form at refrigeration temperature. This makes the oil

suitable for salad making. It has a high oleic acid and low polyunsaturated fatty acid (linoleic acid and linolenic acid), enough to cover daily minimum needs for an adult (around 10 g) and low acidity (**Ezebor *et al*., 2005**). It also has higher oxidative stability than other oils, due to the presence of polyunsaturated fatty acids and gamma-tocopherol (**Shaker *et al*., 2009**). It is regarded as high quality oil and is highly recommended for cooking over other oils because it is more resistant to chemical decomposition at high temperatures (**Shaker *et al*., 2009**). Furthermore, less fat is absorbed into the food as it creates a crust on the surface during cooking, preventing the oil itself being absorbed into the product. In the textile industry, the oil is used to waterproof textile fibers. The oil compares well with corn, soybean, olive and cotton seed oil and can thus serve as a substitute for these oils especially in times of scarcity. The oil is a potential source of biodiesel and much research has been conducted in that area (**Bamishaiye *et al*., 2011**). The broad objective of this study was to increase the utilization of tiger nut and its oil from different cultivars and evaluate the physico- chemical properities as well as study the shelf stability of plantain chips fried in the oil.

MATERIAL AND METHODS

Procurement of Raw Materials

Brown and yellow tiger nuts were purchased from North bank market Makurdi, while the black tiger nut was purchased fromVandeIkya market, all in Benue State, Nigeria. They were taken to the Department of Agronomy, Federal University of Agriculture,Makurdi for identification.

Tiger nut flour Production

Tiger nut flour was produced following the method of Adejuyitan (2011) as shown in Figure 1. The samples were separately cleaned, washed and oven dried at 103°C for 1hr. Theywere milled and sieved into flour.

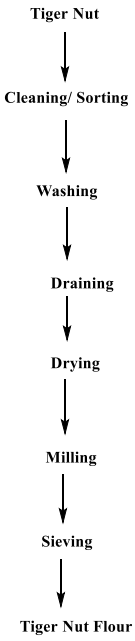

Figure 1 Flow chart for tiger nut flour Production (**Adejuyitan, 2011**).

Extraction of tiger nut oil

Tiger nut oil was extracted from the resulting flour using n-hexane (anon–polar solvent)according to **AOAC (2012)** as presented in Figure 2. Flour samples (1050g sample A,1050g for sample B and 1050g for sample C) wereused for extraction using a soxhlet extractor. The lipid was extracted for 5 hr.With a 500ml volumetric flask containing the solvent,which was heated with an electricheater at 70°C. Oil/solvent extracts were evaporated off using rotary evaporator and later oven dried at 105°C for 1 hr and stored in bottles to be analyzed later.

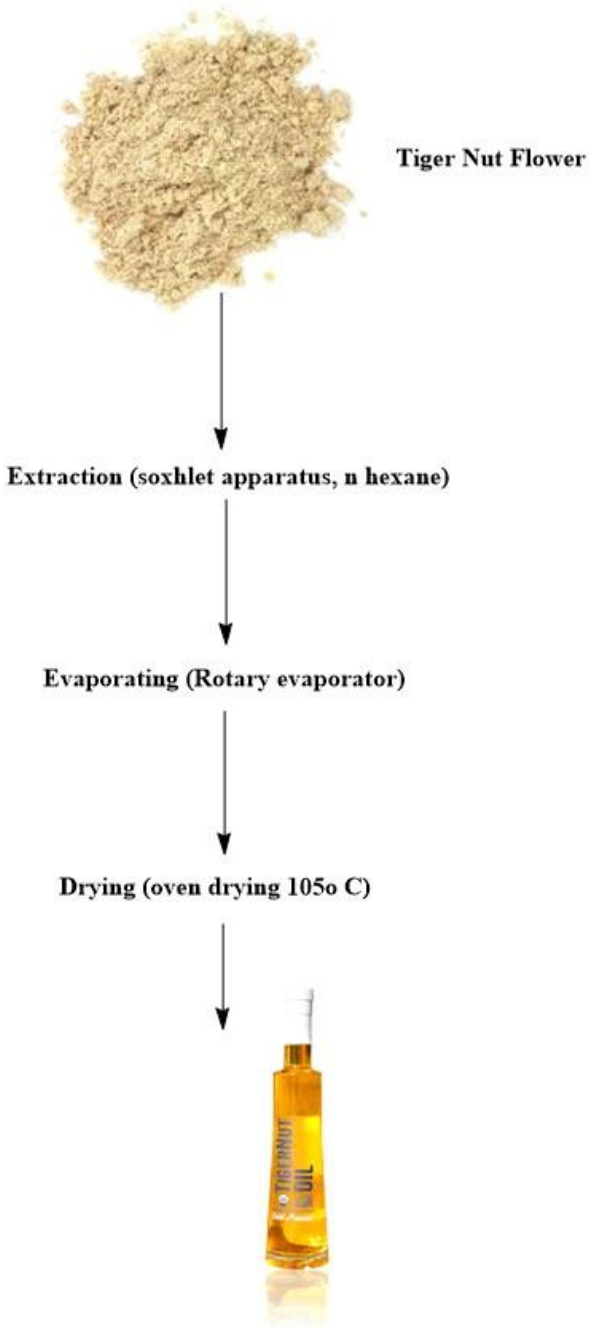

Figure 2 Flow chart for extraction of oil from tiger nut **(Bamishaiye *et al*., 2011).**

Analysis of physiochemical parameters of tiger nut oil

Peroxide Value

Peroxide value (PV) is a measure of the concentration of a substance that can oxidize potassium iodide to iodine (**Sadoudi *et al*., 2017**). It is a mili equivalents of oxygen (hydro peroxides) per 1000 gram of oil. This was done by the **AOAC (2012).**

Oil sample (2.0 g) was accurately weighed into a conical flask, and dissolved in solvent mixture containing 12 ml chloroform and 18 ml glacial acetic acid. To the solution 0.5 ml of a saturated aqueous potassium iodide solution was added. The flask was stoppered and allowed to stand for 1 min. Thirty milliliters of water was added and the solution was titrated with 0.1 M sodium thiosulphate solution until the yellow color had almost gone. About 0.5 ml of starch solution was introduced and titration continued with the reagent added slowly until the blue black color disappeared. During titration, the flask was continuously and vigorously shaken to transfer the liberated iodine from the chloroform layer to the aqueous layer. A blank titration was also performed, and the peroxide value was obtained from the formula (**Sadoudi,*.et al*., 2017**):

$$PV(\text{meq } O_2/\text{Kg Oil}) = \frac{(V - V_0) * N}{m} * 10^3$$

Where PV is peroxide value; V= volume of $Na_2S_2O_2$ solution used for the sample test (in mL); V_0= volume of $Na_2S_2O_2$ solution used for the blank test (in mL); N= normality of $Na_2S_2O_2$ solution; m =weight of the oil sample taken (in g)

Saponification Value

This is the weight of potassium hydroxide, in milligrams, needed to saponify one gram of oil (**Sadoudi,*et al*., 2017**).Two grams of sample was accurately weighed and placed in a 250ml flask and 25ml of a mixture of equal volumes of ethanol and potassium hydroxide added. The mixture was heated in a water bath (coupled to a reflux condenser from the soxhlet extractor) for 30 minutes while being stirred continuously. One milliliter of phenolphthalein indicator was added and the resulting mixture titrated with 0.5N hydrochloric acid. A blank procedure was carried out and the saponification value calculated using the formula below:

$$SV = \frac{N \times Eq \times (V0 - V1)}{P} \times 10^3$$

Where SV =saponification value, (mg KOH/ g oil); V_0=volume of hydrochloric acid solution required for the blank, (mL); V_1= volume of hydrochloric acid solution required for the sample, (mL); N =normality of HCl solution (0.5N); Eq=equivalent gram of KOH (56.1 g/mol); p= weight of the oil sample (g).

Thiobarbituric acid value

Thiobarbituric acid value was determined according to the method described by **Benchamaporn et al. (2009).** A fifty (50) milligram sample was accurately weighed into a twenty-five milliliter volumetric flask and dissolved in a small volume of 1-butanol and made up to volume with 1-butanol. Then 0.5 mL of the sample solution was transferred to a dry test tube and 5 mL of TBA reagent solution (0.2883G/100ml of 90% glacial acetic acid) added. The test tube was closed with a ground-glass stopper, mixed thoroughly and placed in a thermostatic bath at 95°C. After 120 min, the test tube was removed from the thermostatic bath and cooled under running tap water for about 10 min until it reaches room temperature. The absorbance of the reaction solution was then measured at 530nm using distilled water in the reference cuvette. A reagent blank was also prepared and read. The result was calculated using the equation below:

$$\text{TBAR value} = \frac{[50 \times (A - B)]}{m}$$

Where A = absorbance of the test solution, B = absorbance of the reagent blank, m = the weight (g) of the test sample.

Iodine Value

The iodine value (IV) indicates the degree of unsaturation of the oil. It is defined as the number of grams of iodine absorbed by 100 grams of oil (**Sadoudi *et al*., 2017**). The method described by **Nadeem et al. (2013)** was used to determine the iodine value. 0.2g of oil sample was weighed and placed in a 250mL flask and 20mL of chloroform was then added to the sample.Wijs reagent (25ml)wasadded with the aid of a pipette and the resulting mixture stirred and stored in a dark place at 25°C for 30 minutes before 10mL of 30% potassium iodide was added to the mixture as well as 100mL of distilled water. The mixture was then titrated with 0.1N sodium thiosulphate until the yellow colour almost disappeared. One milliliter of starch solution was then added and the mixture titrated further until the blue starch-iodine colour disappears. A blank titration was also carried out and the Iodine value calculated using the formula below:

$$\text{Iodine value} = \frac{\text{TD} \times 1.269}{\text{M}}$$

Where TD=Titre difference, M= mass of sample(g), 1.269= constant

Acid Value

Five (5) grams of sample was weighed and placed in a 250mL flask and fifty (50) milliliter of a mixture of equal volumes of ethanol and ether, which has been neutralized by 0.5N of potassium hydroxide, was then added. The resulting mixture was heated for 10 minutes to allow for complete dissolution of the sample and then cooled. One milliliter of phenolphthalein indicator was then added while shaking the contents vigorously. The mixture was then titrated with 0.5N potassium hydroxide until a pink colour was obtained as described by **AOAC (2000)**. The entire procedure was repeated for a blank analysis. The acid value was then calculated using the formula:

$$\text{Acid value} = \frac{TD \times N \times 56.1}{M}$$

WhereTD= Titre Difference = B – S, B= Titre value blank; S= Titre value with sample; N= Normality of titrating solution (KOH used herein), M= Mass of sample (g) , 56.1 = molar mass of KOH; The free fatty acid value is usually regarded as half the acid value of the oil.

Free Fatty acid (FFA) content

A clean dry beaker was weighed and 2 g of pre-heated oil (heated to about 50°C) was added and reweighed Aliquots of ethanol was added to the oil to completely free the fatty acids and the ethanol-oil mixture was then titrated with 0.1N NaOH using phenolphthalein indicator. The volume (V) of NaOH required to produce the first permanent pink colour was recorded and the free fatty acid content of the oil was determined from the formula:

$$\% \text{ FFA} = \frac{\text{M} \times \text{V} \times \text{N}}{10 \times \text{m}}$$

Where M = Relative molecular mass of Palmitic acid =256, V = volume of NaOH used, N = Normality (concentration) of NaOH used, m = Weight of oil used, 10= constant. **AOAC(2000).**

Determination of specific gravity

The specific gravity bottle (Pycnometer)was used in measuring the density/specific gravity of the sample. The specific gravity of oil is the ratio of the weight in air of a given volume of the oil at a defined temperature to that of the same volume of water at same temperature (**AOAC, 2012**). Cleaned, dried pycnometer was weighed. It was filled with water maintained at 20ºC and weighed again. The bottle was emptied, dried and filled with oil and weighed. The specific gravity was calculated using the formula shown:

$$\text{Specific gravity} = (W_3 - W_2) / W_1$$

Where W_3 = weight of container and oil, W_2 = weight of empty container, W_1 = weight of equal volume of water.

Determination of Refractive Index

The refractive indices, η40 D, (RI), of the oils and fat samples were measured using the Abbe refractometer connected to a thermostatically controlled water bath that maintained the temperature of the refractometer at 40 ± 0.1ºC used. A drop of the oil was placed on the surface of the refractometer and the reading was taken.

Determination of moisture value

Moisture content of tigernut oil was determined by the **AOAC (2000**). Intodried, and weighed moisture dish was added 5g tiger nut oil. This was heated in an oven(Memmert, Germany) at 105◦C for 1 hour, cooled in a desiccator containing phosphorus peroxide and weighed. This was repeated until a constant weight obtained.

$$\% \text{ Moisture} = \frac{Ms - Mh}{Ms - Mt} \times 100$$

Where, Ms = Weight of moisture dish + Sample (g), Mh = Weight of moisture dish +sample after heating(g), Mt = Weight of Tare/moisture dish(g)

Analysis of fatty acid composition of tiger nut oil

About fifty (50) mg of the extracted oil was saponify for 5 min at 95ºC with 3.4 mL of 0.5 M KOH in dry methanol. The mixture was neutralized by 0.7 M HCl. About 3 ml of 14 % boron triflouride in methanol was added (**AOAC, 2010**). The mixture was heated for 5 min at 90ºC to achieve complete methylation process. The fatty methyl esters were thrice extracted from the mixture with redistilled n-hexane. The content was concentrated to 1 ml for analysis and 1µL was injected into the injection pot of the gas chromatograph (GC-MS). The fatty acid methyl esters separation was performed on a gas chromatographof the type Trace GC Ultra in mode Split, equipped with a flame ionization detector (FID) witha capillary column DB-5 (30m x 0.32 mm ID; ϕ1 µm film thickness (Agilent Technologies, J&W Scientific Products, USA) at Department of Chemistry Laboratory, South campus, Nelson Mandela University, South Africa. Helium was used as the carrier gas at a flow rate of 1 ml/min. The injector temperature was maintained at 250°C. 1µL of the sample was injected undiluted in 100:1 split ratio.

RESULTS AND DISCUSSION

Physiochemical Properties of Tiger Nut Oils

Table 1 presents the physiochemical properties of tiger nut oil. The values of the refractive index, specific gravity, acid value and free fatty acid ranged between 1.46-1.47, 0.89-0.90, 0.45-1.4, and 0.20-0.75 respectively. The peroxide value, saponification value and iodine value ranged between 3.99-4.43, 183.25-202.87, 29.69-31.74 respectively. There was significant ($p<0.05$) difference in the acid value, free fatty acid, peroxide value, saponification value and iodine value while there was no significant ($p>0.05$) difference in the refractive index and specific gravity. Sample C (brown cultivar) had the highest refractive index, followed by sample A (black cultivar) and B (brown cultivar), for the specific gravity, sample C (yellow cultivar) also had the highest value followed by sample A (black cultivar) while sample C (yellow cultivar) had the least value. The acid value of sample B (brown cultivar) was higher followed by sample C (yellow cultivar) while sample A (black cultivar) had the least value. The free fatty acid value of sample B (brown cultivar) was higher followed by sample C (yellow cultivar) while sample A (black cultivar) had the least value. The peroxide value of sample B (brown cultivar) had the highest value, followed by sample C (yellow cultivar) while sample A (black cultivar) had the least value, the saponification value of sample A (black cultivar) had the highest value followed by sample C (yellow cultivar) while sample B (brown cultivar) had the least value. The iodine value of sample C (yellow cultivar) had the highest value.

Table 1 Physiochemical Properties of Tiger nut oils

Sample	RI	SG	AV (mg/g)	FFA %	PV (meq/kg)	SV (mg/KOH)	IV ($g/I_2/g$)
A	$1.462^{a}\pm0.00$	$0.89^{a}\pm0.00$	$1.40^{a}\pm0.14$	$0.75^{a}\pm0.07$	$4.43^{a}\pm0.03$	$202.87^{a}\pm0.55$	$31.74^{b}\pm0.24$
B	$1.462^{a}\pm0.00$	$0.89^{a}\pm0.00$	$0.76^{b}\pm0.02$	$0.38^{b}\pm0.01$	$4.03^{b}\pm0.01$	$183.25^{b}\pm3.09$	$29.69^{c}\pm0.33$
C	$1.465^{a}\pm0.00$	$0.90^{a}\pm0.00$	$0.45^{c}\pm0.03$	$0.20^{c}\pm0.01$	$3.99^{c}\pm0.01$	$198.24^{a}\pm0.01$	$32.79^{a}\pm0.18$

Values are Means ± standard deviation of duplicate determinations. Mean values down the column followed by different superscripts are significantly ($p\leq0.05$) different.
Key: RI- Refractive index, SG- specific gravity, IV-Iodine value, AV- acid value, FFA-free fatty acid, PV-Peroxide value, SV-saponification value, Sample A = Black tiger nut oil, Sample B =Brown tiger nut oil, Sample C =Yellow tiger nut oil.

Fatty acid Composition of Tiger Nut Oil

The fatty acid composition of tiger nut oil samples shows a range of 14:1 to 24:1 (Table 2). Twelve (12) compounds were identified including saturated, monounsaturated and polyunsaturated fatty acid. The saturated fatty acids comprised of palmitic acid (16:0), stearic acid (18:0) and arachidic acid (20:0) while the mono unsaturated fatty acid comprised of three monoenes namely: myristoleic (14:1), palmitoleic acid (16:1), oleic acid (18:1) and elaidic acid (18:1), gadoleic acid (20:1), erucic (22:1), nervonic (24:1), two poly unsaturated fatty acid linoleic acid (18:2), dihumo- g- linolenic acid(20:3). The percentage fatty acid of the black cultivar contained palmitic (16.17%), stearic (5.8%), oleic (77.71%) and heneicosylic (0.31%) fatty acids. The brown cultivar contained palmitic (11.86%), stearic (6.26), oleic (64.12%), linoleic (11.87%), dihumo- g- linolenic (1.71%). arachidic (1.87%), gadoleic (0.90%), henicosylic (1.87%), eruvic (0.63%), nervonic (2.32%), while the yellow cultivar contained mystrioleic (0.06%), palmitic (13.33%), palmitioleic (0.30%), stearic (4.46%), oleic (68.89%), linoleic (12.77%), and heneicosylic (0.18%) fatty acids. The unsaturated fatty acid of the oil samples from the different cultivars was higher than the saturated fatty acids. The five predominant fatty acids present in the oil samples include palmitic, oleic, linoleic, stearic, and heneicosylic. The highest percentage of palmitic acid was present in the black cultivar (16.17%) followed by the yellow cultivar (13.33%) while the brown cultivar (11.68%) had the least amount. The highest percentage of oleic acid was present in the black cultivar (77.71%) followed by the yellow cultivar (68.89%) while the brown cultivar (64.12%) had the least amount. The highest percentage of linoleic acid was present in the yellow cultivar (12.77%) followed by the brown cultivar (11.87%) but not detected in the black cultivar. The highest percentage of stearic was present in the brown cultivar (6.26%) followed by the black cultivar (5.81%) while the yellow cultivar (4.46%) had the least amount. The highest percentage of heneicosylic was present in the brown cultivar (0.51%) followed by the black cultivar (0.31%) while the yellow cultivar (0.18%) had the least amount.The total unsaturated fatty acid was higher in the brown cultivar (82.05%), followed by the yellow cultivar (82.02%) while the black cultivar had the least value (77.71%) while the total saturated fatty acid was higher in the black cultivar (22.78%) followed by the brown cultivar (19.34%) while the brown cultivar had the least value (17.97%).

Table 2 Fatty acid Composition of Tiger nut oil

Lipid number	Systematic name	Trivial name	A	B	C
C: 14.1	Cis- 9- tetradecanoic	Myristoleic	ND	ND	0.06
C:16.0	Hexadecanoic acid	Palmitic	16.17	11.86	13.33
C:16.1	Cis -9- hexadecanoic	Palmitioleic	ND	ND	0.30
C:18.0	Octadecanonic	Stearic	5.81	6.26	4.46
C:18.1	Cis- 9 -octadecanonic	Oleic	77.71	64.12	68.89
C:18.2	9 ,12 octadecanonic	linoleic acid	ND	11.87	12.77
C:20.0	Eicosanoic acid	Arachidic	ND	0.90	ND
C:20.1	Cis -11- eicosenoic	Gadoleic	ND	1.87	ND
C:20.3	8,11,14 eicosatrienonic	dihumo-g-linolenic	ND	1.71	ND
C:21.0	Heneicosanoic	Heneicosylic	0.31	0.50	0.18
C:22.1	Cis- 13- docosenoic	Erucic	ND	0.63	ND
C:24.1	Cis -15-tetracosenoic	nervonic	ND	2.32	ND
SFA			22.78	19.34	17.97
MUFA			77.71	68.94	69.25
PUFA			ND	13.58	12.77
Total SFA			22.78	19.34	17.97
Total USFA			77.71	82.52	82.02

Key: SFA: Saturated fatty acid, MUFA: Monounsaturated fatty acid, PUFA: Polyunsaturated fatty acid, USFA: Unsaturated fatty acid, ND: Not detected

Storage Stability of Tiger Nut Oils

Results of the storage stability of tiger nut oil samples and plantain chips fried using the oil is presented in table 4. Parameters of Storage stability include free fatty acid (FFA), thiobarbituric acid (TBA) values, Peroxide values and moisture content.

Free Fatty acid

Result of the effect of storage on free fatty acid of tiger nut oil is shown in Table 3. The Free fatty acid values of the stored oil for sample A from 0 to 12 weeks ranged between 0.65−0.87%, sample B (0.38−0.41%) while sample C ranged from 0.19−0.22%. The Free fatty acid values for sample A and B increased during storage while in sample C; there was an unsteady decrease in free fatty acid during storage.

Table 3 Effect of Storage on theFree Fatty acid of Tiger nut oil

	Storage time						
SAMPLE	0	2	4	6	8	10	12
A	0.75_a^c±0.00	0.83_a^b±0.00	0.85_a^b±0.00	0.87_a^a±0.00	0.87_a^a±0.00	0.87_a^a±0.00	0.87_a^a±0.00
B	0.38_b^a±0.01	0.38_b^b±0.00.	0.39_c^b±0.00	0.41_b^a±0.00	0.41_b^a±0.00	0.41_b^a±0.00	0.41_b^a±0.00
C	0.20_c^b±0.02	0.22_c^a±0.00.	0.19_b^c±0.00	0.22_c^a±0.00	0.22_c^a±0.00	0.21_c^a±0.00	0.21_c^a±0.00

Values are Means ± standard deviation of triplicate determinations. Means values downthecolumn followed by different superscripts are significantly ($p \leq 0.05$) different. Keys: Superscripts: Separation of means for Week, Subscripts: Separation of means for samples, Sample A= Black tiger nut, Sample B= Brown tiger nut, Sample C=Yellow tiger nut.

Thiobarbituric acid

Result of the effect of storage on thiobarbituric acid of tiger nut oil is shown in table 4. The thiobarbituric acid values of the stored oil for sample A form 0 to week 12 ranged between 0.39−0.49 malon/mg, sample B ranged from 0.48−0.51 malon/mg while sample C ranged between 0.30− 0.35 malon/mg. The Thiobarbutuirc acid values for samples A and B increased during storage while in sample C; there was an unsteady decrease in thiobarbituric during storage.

Table 4 Effect of Storage on the Thiobarbituric acid (malon/mg) of Tiger nut oils

samples	**Storage Time**						
	0	2	4	6	8	10	12
A	0.39_b^c±0.00	0.43_b^b±0.00	0.45_b^a±0.00	0.45_b^b±0.00	0.45_b^b±0.00	0.49_b^a±0.00	0.49_b^a±0.00
B	0.48_a^b±0.00	0.50_a^a±0.00	0.50_a^a±0.00	0.50_a^a±0.00	0.51_a^a±0.00	0.51_a^a±0.00	0.51_a^a±0.00
C	0.30_c^b±0.00	0.35_c^a±0.00	0.34_c^a±0.00	0.30_c^b±0.00	0.30_c^b±0.01	0.31_c^b±0.00	0.30_c^b±0.01

Values are Means ± standard deviation of duplicate determinations. Mean values down the column followed by different superscripts are significantly ($p \leq 0.05$) different. Keys: Superscripts: Separation of means for weeks, Subscripts: Separation of means for samples, Sample A =Black tiger nut, Sample B =Brown tiger nut, Sample C =Yellow tiger nut.

Moisture content of tiger nut oils

Result of the effect of storage on moisture content of the tiger nut oils is shown in Table 5. The moisture content for sample A from 0 to week 12 ranged between 2.33−2.46%, sample B ranged between 2.48−2.71% while sample C ranged between 2.03−2.18%. The moisture content of sample A, B, C increased during storage but did not differ ($p<0.05$) significantly.

Table 5 Effect of storage on the moisture content of Tiger nut oil

samples	**Storage Time (Weeks)**						
	0	2	4	6	8	10	12
A	2.33_b^d±0.00	2.34_b^c±0.00	2.38_b^b±0.00	2.42_b^a±0.01	2.44_b^a±0.00	2.46_b^a±0.00	2.45_b^a±0.00
B	2.48_a^d±0.02	2.55_a^c±0.01	2.59_a^c±0.00	2.71_a^a±0.00	2.65_a^b±0.02	2.72_a^a±0.03	2.62_a^b±0.02
C	2.03_c^d±0.00	2.09_c^c±0.00	2.15_c^b±0.05	2.18_c^a±0.00	2.18_c^a±0.00	2.16_c^b±0.00	2.08_c^d±0.00

Values are Means ± standard deviation of duplicate determinations. Means values down the column followed by different superscripts are significantly different ($p \leq 0.05$).
Keys: Superscripts: Separation of means for months, Subscripts: Separation of means for samples, Sample A=Black tiger nut, Sample B =Brown tiger nut, Sample C =Yellow tiger nut.

Peroxide value

Result of the effect of storage on peroxide value of the tiger nut oil is shown in Table 6. Peroxide value of sample A from 0 to week 12 ranged between 5.50−5.77 meq/kg, sample B ranged between5.67−5.85meq/kg, while sample C ranged between 4.27−4.36meq/kg. The peroxide value of the three samples decreased ($p<0.05$) significantly during the storage period.

Table 6 Effect of Storage on the Peroxide Value (meq/kg) of Tiger nut oil

samples	**Storage Time (Weeks)**						
	0	2	4	6	8	10	12
A	5.76_a^a±0.00	5.77_a^b±0.00	5.73_a^c±0.00	5.53_b^d±0.00	5.50_b^d±0.00	5.50_b^d±0.00	5.50_b^d±0.00
B	5.85_b^a±0.01	5.77_a^b±0.00	5.68_b^c±0.01	5.68_a^c±0.00	5.67_a^c±0.01	5.68_a^c±0.00	5.68_a^c±0.00
C	4.36_c^a±0.01	4.27_b^c±0.02	4.28_c^c±0.01	4.30_c^b±0.00	4.32_c^b±0.00	4.31_c^b±0.00	4.32_c^b±0.00

Values are Means ± standard deviation of duplicate determinations. Means values down the column followed by different superscripts are significantly ($p \leq 0.05$) different. Keys: Superscripts: Separation of means for weeks, Subscripts: Separation of means for samples
Sample A =Black tiger nut
Sample B =Brown tiger nut
Sample C =Yellow tiger nut.

Free Fatty acid

Result of the effect of storage on free fatty acid of tiger nut oil is shown in table 7. The Free fatty acid values of the stored oil for sample A from 0 to 12 weeks ranged between 0.65−0.87%, sample B (0.38−0.41%) while sample C ranged from 0.19−0.22%. The Free fatty acid values for sample A and B increased during storage while in sample C; there was an unsteady decrease in free fatty acid during storage.

Table 7 Effect of Storage on the Free Fatty acid of Tiger nut oil

samples	Storage Time (Weeks)						
	0	2	4	6	8	10	12
A	$0.75_a^c \pm 0.00$	$0.83_a^b \pm 0.00$	$0.85_a^b \pm 0.00$	$0.87_a^a \pm 0.00$	$0.87_a^a \pm 0.00$	$0.87_a^a \pm 0.00$	$0.87_a^a \pm 0.00$
B	$0.38_b^a \pm 0.01$	$0.38_b^b \pm 0.00.$	$0.39_c^b \pm 0.00$	$0.41_b^a \pm 0.00$	$0.41_b^a \pm 0.00$	$0.41_b^a \pm 0.00$	$0.41_b^a \pm 0.00$
C	$0.20_c^b \pm 0.02$	$0.22_c^a \pm 0.00.$	$0.19_b^c \pm 0.00$	$0.22_c^a \pm 0.00$	$0.22_c^a \pm 0.00$	$0.21_c^a \pm 0.00$	$0.21_c^a \pm 0.00$

CONCLUSION

The result of the study provides information on the nutritional composition, physico-chemical and functional properties of tiger nut flour and oil from different cultivars.

Tiger nut flour is a rich source of some useful mineral elements such as potassium, phosphorus, zinc, sodium and calcium which are necessary for body growth and development.

Twelve different individual fatty acids were identified, with 18:1n−9 oleic predominating in the studied samples. The edible and stable oil obtained from the tuber is said to be superior oil that compares favorably with olive oil. The results of this study have provided much justification for the use of tiger nut oil in food products. The high content of oleic acid makes tiger nut oil a very nutritious and health enhancing oil. Thus tiger nut oil should be developed into a commercial product for use in food products. The sensory properties of the oil fried with plantain chips showed that the oil is useful for cooking and frying since it has good taste and aroma.

The effect of storage on some of the physiochemical parameters (thiobarbituric acid TBA, free fatty acid, Peroxide value, Moisture content) analyzed for both the chips and oil samples showed that there was both increase and decrease during storage but they did not exceed the maximum limits as recommended by CODEX Alimentarius indicating that tiger nut oil is also a good oil and can play important roles in providing food security, enhancing livelihoods, improving nutritional status and social wellbeing of vulnerable groups. Tiger nuts and its products could thus, go a long way in aiding to alleviate problems of malnutrition.

Recommendations

- The high content of oleic acid makes tiger nut oil a very nutritious and health enhancing oil, thus recommended to be developed into a commercial product for use in food products.
- Tiger nut flour is rich in other nutrients thus it is recommended for use in food systems.

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