

Physicochemical and nutritional values of tiger nut (*Cyperus esculentus*) oil from three regions of Côte d'Ivoire

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Abstract

In many rural areas of West Africa, the consumption of lipids by farmers is one of the problems affecting their nutrition and even their health. In Côte d'Ivoire, tiger nut, consumed as part of the traditional diet of rural populations in the north and centre of the country, is a potential source of dietary lipids. The aim of this study was to contribute to the valorisation of tiger nuts (*Cyperus esculentus*) through the physico-chemical characterisation of the oil extracted from tubers from three regions of Côte d'Ivoire. To do this, samples of tiger nut tubers were collected and the oil was extracted using standard methods. Tiger nut oils exhibited satisfactory physicochemical characteristics, with acid value ranging from 0.13 to 3.14 mg KOH/g oil, iodine value from 68.92 to 94.54 g I₂/100 g oil and saponification value from 174.2 to 185.13 mg KOH/g oil. The oils were rich in polyunsaturated fatty acids, with oleic acid being the most abundant (73 - 80%) and demonstrated greater oxidative indexes. Tiger nut oil from the three regions contained significantly higher levels of α -tocopherols and polyphenols. Due to these characteristics and nutritional properties, tiger nut oil presents significant potential for application in food, nutraceutical and cosmetic industries.

Keywords: Tiger nut tubers; oil extract, physicochemical properties, fatty acids; antioxidants.

Introduction

In Côte d'Ivoire, as in many other countries in West Africa, the nutritional needs of the population, estimated at 1 800 000 tonnes/year to ensure a quality diet, are far from being met (FAO, 2023). The population of Côte d'Ivoire, like that of most underdeveloped countries, consumes too few calories from fat. There is a significant difference between rural and urban populations; the former consumes less fat than the latter and their lipid diet is not necessarily balanced (Sahoré et al, 2017). Several oilseed crops are grown in the countryside, the best-known being cotton seeds, shea butter and oil palm. It seemed attractive to target additional oilseeds with very low value added and significant scientific and technological interest (Kanaté et al., 2025). Increasing the amount of lipids produced from these oilseeds will almost certainly lead to an improvement in the diet and hence the health of the population (Ouille et al., 2017). Several species, including tiger nut (*Cyperus esculentus* L.), have been identified as a result of a number of studies carried out in different parts of the country (Yao et al., 2020; Nikiema et al., 2024).

Tiger nut is a sedge that also grows as a perennial or annual herb which is currently distributed mainly in Spain, Australia, North and South America, China and Africa (Yapi et al., 2012; Zhang et al., 2023). It is a high-yielding, high-value and commercially useful crop with multiple uses (Okoye & Ene, 2018). Tiger nut is rich in starch, with a content of 25-40 %, in carbohydrates (15-20 %) and protein (5-10 %) (Kouame et al., 2022; Wu et al., 2024). In addition, tiger nut is rich in dietary fibre (8-10 %), vitamins C and E (8-14 mg/100g), minerals (potassium, phosphorus, sodium, calcium, magnesium), polyphenols and other bioactive substances (Djikeng et al., 2022; Imo et al., 2024). Tuber has recently gained popularity as a functional food due to its biological properties, which include antioxidants, antibacterial, anti-inflammatory, anticancer, anti-sickling, aphrodisiac, anti-atherosclerotic and hepatoprotective effects (Olabiya et al., 2017; Rebezov et al., 2021).

Tiger nut is widely used in Côte d'Ivoire, where it is known as tchongon in Malinké, Bété, Dida, and Bambara, atadjo in Apolo, shop in Koulango, and maguélé in Sénoufo (Alloko et al., 2022a). It is mostly produced in the country's northern and central regions, with three forms including black, brown, and yellow. Tiger nut tubers can be consumed raw, roasted, or ground into beverages and flour. Edible oil potentials of tiger nut tuber grown in Côte d'Ivoire was investigated (Alloko et al., 2022a; Yao et al., 2020). Despite its high value in industrial applications, tiger nut oil is undervalued in Côte d'Ivoire. In fact, the oil from the tubers is still not part of the local diet. Therefore, this study investigates the physiochemical properties and nutritional benefits of tiger nut oil. The data will inform on the nutritional value of the seed and assist in assessing seed oils for additional applications, including biodiesel and oleochemical sources, thereby enhancing the value of these oils in the country.



Materials and Methods

Materials

The tiger nut tubers used in the research were provided from three regions in the North and the centre north of Côte d'Ivoire. The regions were Dabakala (Hambol region, 7° 41' north, 5° 01' west), Ferké (Tchologo region, 9° 35' north, 5° 11' west) and Korhogo (Poro region, 9° 25' north, 5° 38' west). Yellow tiger nut tubers were collected from January to March 2024 from a pool of women traders in each zone at a rate of 5 kg per woman. A total of 50 kg of tiger nut tubers were collected from each zone and taken to the laboratory for further examination. The tubers were sorted to eliminate those with defects and 5 kg was deducted after homogeneous mixing of the samples collected from each zone. This final quantity was sun dried for one week. The dried seeds were then ground using a hammer mill (Forplex). The ground seeds were sealed and stored in a desiccator until analysis.

Oil extraction

Tiger nut oil was obtained after maceration of the ground tiger nuts mixed with n-hexane at a ratio of 1:10 (g/v) for 6 hours at room temperature. The hexane was removed after extraction using a rotary evaporator (BÜCHI). The oil obtained from each sample was stored in a dark bottle in a refrigerator at 4°C until it was used for various analyses. The yield of lipid extraction was calculated according to formula (1): Yield (%) = (m0/m1) × 100 (1) m0 is the mass of the extracted fat (g), m1 is the mass of the ground tiger nuts.

Analysis of oil quality

Quality indexes

The standard methods of the International Organisation for Standardisation (ISO) were used to analyse oil quality. Acid value and free fatty acid content (ISO 660); iodine value (ISO 3961); peroxide value (ISO 3960); saponification and ester values (ISO 3657); unsaponifiable matter (ISO 3596); refractive index (ISO 6320); relative density (ISO 6883); insoluble impurities (ISO 663); anisidine value (ISO 6885); unsaponifiable matter (ISO 3596). The Totox value was calculated according to the following equation as mentioned by Djikeng et al. (2024): Totox = 2 PV + AV. Titrimetric methods were used to determine the acid, peroxide, iodine and saponification values of all samples.

Polyphenols content

Polyphenols content was evaluated by the Folin-Ciocalteu colorimetric method according to Michui et al. (2022) with slight modifications. The samples were prepared according to the following procedure: 2 g of the tiger nut was dissolved in 5 mL of hexane in an Erlenmeyer flask. Liquid-liquid extraction of antioxidants from the oil sample was then performed three times with 5 mL of methanol. Then the methanolic phase is recovered using a separating funnel. A total of three identical extractions are performed and the methanolic phases are collected and concentrated in the rotary evaporator. 50 µL of the methanol fraction was treated with 1 mL of Folin-Ciocalteu reagent diluted tenfold in distilled water. This mixture was incubated for 10 min. To this sample, 1 mL of sodium carbonate solution (7%, m/v) was added. Absorbance was measured at $\lambda = 760$ nm relative to distilled water. The total polyphenols were expressed in mg GAE/100g oil. A blank solution was also prepared in the same way, using an equivalent amount of methanol instead of the extract.

Vitamin A and Tocopherol Content

Analysis of retinol and α -tocopherol was performed by high pressure liquid chromatography (Acquity UPLC chromatograph, Waters Corporation, Milford, MA, USA) according to ISO 14565. Vitamin and tocopherols were identified based on retention times determined separately for retinol and α -tocopherol, and their contents were estimated using external calibration curves.

Analysis of Fatty Acids

To evaluate the fatty acid content of tiger nut oil, fatty acid methyl esters were prepared according to the SRPS EN ISO 12966-2 method. Fatty acid composition was analysed by gas chromatography (3900, Varian CPG, Sydney, Australia) equipped with a flame ionisation detector and a capillary column CP - select CB for FAME fused silica WCOT (50 m × 0.25 mm, d = 0.25 µm). Helium was used as the carrier gas. The initial column temperature of 140 °C was held constant for 3 min, then increased to 220 °C (at a rate of 3 °C/min) and held for 5 min. Finally, the column temperature was raised to 240 °C (at a rate of 2 °C/min) and held for 10 min. The injector and detector temperatures were set at 250 °C. The individual peaks were identified by comparison of their retention times with the standard mixture of 18 FAME methyl esters. The results were expressed as percentage by weight of the total fatty acid content.

Statistical Analysis

The results of the chemical analyses performed in triplicate were analysed statistically using IBM SPSS Statistics 20 (IBM, Chicago, IL, USA). Tukey's multiple comparison procedure was used to compare the obtained results to each other. Identical letters in rows denote the lack of differences at a significance level $\alpha = 0.05$.



Results and Discussion

Results

Physico-chemical parameters

The physico-chemical parameters of tiger nut oil from the different regions are shown in Table 1. The analysis indicated that there was not a significant difference ($P>0.05$) in all the parameters analysed except for insoluble impurities. The same observation was noted on the oil yield percentage obtained for these three regions ($P>0.05$). Regarding the insoluble impurities, values obtained from the tiger nut oil samples ranged from 0.005 to 0.02%. Regarding the acid value of the tiger nut oil samples, the results show a significant difference ($p<0.05$) with the three regions and all the tiger nut oil samples have lower values (from 0.13 to 3.14 mg KOH/g oil) than the recommended value of 4 mg KOH/g oil. The same observation was made for free fatty acid with values varying significantly ($p<0.05$) from 0.07% to 1.57%. The Korhogo department recorded the highest percentage. Similarly, the results showed that the iodine value of tiger nut oil from the different regions ranged from 68.92 ± 0.79 to 94.54 ± 6.50 g I₂/100 g oil. The highest value was recorded in Korhogo Department and the lowest in Dabakala Department. The analysis of chemical properties revealed that there was no significant difference ($P> 0.05$) in the parameters of saponification value, ester value and unsaponifiable matter content with values ranging from 174.2 ± 2.70 to 185.13 ± 6.43 mg KOH/g oil, 171.05 ± 2.88 to 183.02 ± 6.15 mg KOH/g oil and 1.48 ± 0.03 to 1.62 ± 0.01 %

Table 1. Physico-chemical properties of tiger nut oil from the three regions

Parameters	Dabakala	Ferké	Korhogo
Yield (%)	14.17 ± 0.93^a	14.73 ± 0.74^a	14.68 ± 0.64^a
Relative density at 20°C	0.91 ± 0.0^a	0.91 ± 0.0^a	0.91 ± 0.0^a
Refractive index	1.4567 ± 0.01^a	1.460 ± 0.01^b	$1.459 \pm 0.01^a^b$
Moisture and volatile contents (%)	8.52 ± 0.01^a	8.57 ± 0.01^a	8.49 ± 0.01^a
Insoluble impurities (%)	0.005 ± 0.003^a	0.01 ± 0.001^a	0.02 ± 0.001^b
Acid value (mg KOH/g)	0.13 ± 0.0^a	2.11 ± 0.27^b	3.14 ± 0.22^c
Free fatty acid (%)	0.07 ± 0.0^a	1.1 ± 0.14^b	1.57 ± 0.11^c
Iodine value (g I ₂ /100 g)	68.92 ± 0.79^a	76.92 ± 3.83^a	94.54 ± 6.50^b
Saponification value (mg KOH/g)	174.38 ± 5.84^a	175.13 ± 6.43^a	174.20 ± 2.70^a
Ester value (mg KOH/g)	174.25 ± 5.84^a	173.02 ± 6.15^a	171.05 ± 2.88^a
Unsaponifiable content (%)	1.53 ± 0.01^a	1.48 ± 0.03^a	1.62 ± 0.01^a

n=3 values are presented as mean±SD. Values followed by the same letters in the same row are not significantly different at $p \leq 0.05$.

Table 2. Oxidative indexes of tiger nut oil from the three regions

Parameters	Dabakala	Ferké	Korhogo
Peroxide value (meq O ₂ /kg)	3.17 ± 0.29^a	3.83 ± 1.15^a	4.05 ± 0.30^a
Anisidin value	2.59 ± 0.12^a	3.40 ± 0.46^b	3.58 ± 0.90^b
Totox value	8.92 ± 0.70^a	11.06 ± 2.76^a	11.68 ± 0.69^a

n=3 values are presented as mean±SD. Values followed by the same letters in the same row are not significantly different at $p \leq 0.05$.

Oxidative indexes

The oxidative indexes analysis of tiger nut oil extracted from the three regions are presented in Table 2. With values ranging from values 3.17 ± 0.29 to 4.05 ± 0.30 meq O₂/kg oil, the peroxide index revealed no significant difference ($P> 0.05$) from the three regions. For the anisidin value, significant differences were found between the tiger nut oil values according to the regions ($p<0.05$). The tiger nut samples from the regions of Ferké and Korhogo had the highest para-anisidine values. As for the Totox value, all types of tiger nut oil samples showed no significant difference ($P> 0.05$) regardless of the three regions.

Polyphenols and vitamins content

The polyphenols and vitamins parameters of tiger nut oil from the different regions are shown in Table 3. The analysis showed that there was a significant difference ($P<0.05$) in all the parameters analysed. Indeed, the content of polyphenols in the evaluated tiger nut oil ranged from 14.81 to 22.54 mgGAE/100 g. Tiger nut oil from Korhogo department contained approximately 1.2 to 1.5 times more polyphenols than tiger nut oils from the other regions. In addition, tiger nut oil from the Korhogo department had the highest vitamins content, with a value of α -tocopherol of 54.12 mg/kg and 7.93 ± 0.37 mg/kg for retinol.

Fatty acids composition of tiger nut oil from the different regions

The fatty acid composition is given in Table 4. The GC analysis results show a significant difference ($P<0.05$) between the free fatty acid compositions of tiger nut oil from the three regions. The most abundant fatty acids in



the tiger nut oil samples were oleic acid (C18:1), linoleic acid (C18:2), palmitoleic acid (C16:1) and stearic acid (C20:0). The main fatty acid found in both materials was oleic acid, $72.69 \pm 1.1\%$ to $79.68 \pm 0.98\%$ in tiger nut oil from the three regions, with Korhogo showing a higher value. Linoleic acid (C18:2) was the second most abundant fatty acid determined in the tiger nut oil sample. The high content of SFA in the tiger nut oil samples from the three regions was attributed to the presence of oleic, linoleic and palmitoleic acids. The PUFA content was slightly higher in tiger nut oil from Korhogo (88.73%) than in tiger nut oil from Ferké and Dabakala (83.42 and 84.51%).

Table 3. Polyphenols and vitamins (tocopherols, retinol) content of tiger nut oil from the three regions

Parameters	Dabakala	Ferké	Korhogo
Polyphenol (mg/100g GAE)	14.81 ± 0.14^a	19.50 ± 0.19^b	22.54 ± 0.59^c
α -tocopherol (mg/kg)	144.11 ± 0.37^b	136.07 ± 0.41^a	154.12 ± 1.03^c
Retinol (mg/kg)	7.37 ± 0.31^{ab}	6.70 ± 0.40^a	7.93 ± 0.37^b

n=3 values are presented as mean \pm SD. Values followed by the same letters in the same row are not significantly different at $p \leq 0.05$.

Table 4. Composition of fatty acids of tiger nut oil from the three regions

Parameters	Dabakala	Ferké	Korhogo
Lauric acid (C12:0)	0.44 ± 0.16^b	0.10 ± 0.0^a	0.13 ± 0.04^a
Myristic acid (C14 :0)	1.29 ± 0.03^c	1.13 ± 0.02^b	0.88 ± 0.06^a
Palmitic acid (C16 :0)	0.34 ± 0.0^a	0.24 ± 0.01^a	0.33 ± 0.10^a
Palmitoleic acid (C16 :1)	9.47 ± 0.80^b	9.25 ± 0.43^b	5.63 ± 0.51^a
Stearic acid (C18 :0)	4.83 ± 0.33^b	4.18 ± 0.21^a	3.72 ± 0.20^a
Oleic acid (C18: 1)	73.31 ± 0.76^a	72.69 ± 1.1^a	79.68 ± 0.98^b
Linoleic acid (C18: 2)	9.64 ± 0.47^b	11.42 ± 0.23^c	8.48 ± 0.30^a
Linolenic acid (C18 :3)	0.13 ± 0.02^a	0.16 ± 0.02^a	0.25 ± 0.03^b
Arachidic Acid (C20 :0)	0.29 ± 0.02^b	0.43 ± 0.04^b	0.72 ± 0.06^c
SFA	16.32	15.09	11.08
MUFA	73.65	72.93	80
PUFA	83.42	84.51	88.73

n=3 values are presented as mean \pm SD. Values followed by the same letters in the same row are not significantly different at $p \leq 0.05$.

Discussion

The results of oil extraction from tiger nut tubers showed no significant difference between the different regions. Oil contents ranged from $14.17 \pm 0.93\%$ to $14.73 \pm 0.74\%$. The oil yield values obtained in this study were lower compared to the one reported by Zhen-Shan Zhang et al (2023) and Keskin et al (2024). However, our values are similar to those of Djikeng et al (2022). These differences can be attributed to the extraction methods and the maturity stage of the tubers (Hsu *et al.*, 2006). The results of the physical characterisation of the tiger nut oil samples show no significant difference in origin, except for impurities. The physical parameters studied were relative density, refractive index, moisture content and impurities. The relative density obtained for the three oil samples is 0.91. This value is comparable to that obtained by Yao et al. (2018) and Aljuhaimi et al. (2018). As for the refractive index values, values obtained were between 1.459 and 1.460 and are comparable to those reported by Adel et al. (2015).

The evaluated tiger nut oils exhibited acid value (AV) ranging from 0.13 to 3.14 mg KOH/g of oil which remained well below the Codex Alimentarius's standard limit of 4 mg KOH/g. These low acid values obtained for tiger nut oil are an indication that the triglycerides present in the tiger nut sample have not been hydrolysed, an indication that the oil is less susceptible to lipase action. Keskin et al (2024) reported that AV values for yellow tuber tiger nut oil obtained through cold-press machine extraction of 3.63 ± 0.02 mg KOH/g of oil. The free fatty acidity (FFA) of the oil ranging from 0.07 to 1.57% linoleic acid. Similar trends were observed for tiger nut oils extracted by different method (Duman, 2019; Miao *et al.*, 2022). The iodine value provides information on the degree of unsaturation of the fatty acids present in the oil. In the current study, iodine values ranged from 68.92 to 94.54 g I₂/100 g of oil. The results are comparable to those reported by Sabah et al. (2019), with an iodine value ranging from 70 to 80 g I₂/100 g of oil. The tiger nut oil samples from the three regions analysed showed an average saponification index of between 174.20 and 175.13 mg KOH/g oil, which is higher than the values reported by Dumas (2019) from chufa seeds varieties in Turkey. The ester indices were of the same order and all slightly lower than their saponification index. The unsaponifiable fraction content varied from 1.48% to 1.62% among the various tiger nut oil samples studied. The unsaponifiable fraction content of the oils examined is higher than that of certain conventional oils such as cotton seed oil (0.52%) and peanut oil (0.33%) (Zoué et al., 2012). The presence of unsaponifiable compounds could add value to these oils, making them suitable for use in the food sectors. The



determination of the PV of oils and fats informed on their primary oxidation state which must be less than 15 meq O₂/kg of oil, the limit recommended by the FAO for vegetable oils intended for human consumption (Codex, 2023). In this study, the peroxide values, between 3.17 and 4.05 meq O₂/kg of oil, were well in line with this recommendation. For an accurate evaluation of the oil's oxidation state, it is crucial to integrate the measurements of the para-anisidine and peroxide values. Para-anisidine value measures the level of secondary oxidation products, such as aldehydes, ketones, hydrocarbons, alcohols, esters, and acids, formed from the breakdown of primary oxidation products (Djikeng et al., 2024). The relatively low *p*-anisidine value of the tiger nut oils suggests that primary oxidation products have not significantly degraded, indicating that the oils were safe for consumption concerning oxidation and hydrolysis products. A Totox value of 10 is the threshold for determining acceptable quality in edible oils (Bojanowska and Lamarska, 2016). The calculated Totox value, as a measure of the total oxidation profile of the tiger nut oils from the three regions, ranged from 8.92 to 11.68 indicates high primary and secondary oxidative stability. Polyphenols are natural antioxidants with the ability to inhibit the oxidation process in oils (Rakita et al., 2024). Results showed an average total polyphenol content ranging from 14.81 to 22.54 mg GAE/100 g which was much lower than total phenol content in tiger nut oil reported by Alloko et al (2022b). However, these results are quite similar to those reported by Zhang et al (2023). The significant quantity of tocopherols found in all tiger nut oil from the three regions could contribute to its high oxidative stability. Similar to this study, previous studies have reported higher concentrations of α -tocopherols in tiger nut oils (Zhang et al., 2023). The low levels of vitamin A (retinol) observed in the tiger nut oils samples could be explained by the absence or very low presence of vitamin A in the form of retinol in tubers plants from which these oils are extracted (Yao et al., 2018). The results obtained could also be influenced by the degradation process of the samples during the assay procedure. The most dominant MUFAs in tiger nut oils from the three regions were oleic acid. Other researchers have shown similar levels of these fatty acids. Higher percentages of oleic acid (66-78%) were reported by several authors (Hu et al., 2018; Guo et al., 2021). Due to its unique fatty acid profile, tiger nut oil could be suitable for direct consumption, including use in the enrichment of various food products. Its potential nutraceutical benefits suggest its use in the development of functional foods and nutraceuticals aimed at promoting health (Zhang et al., 2023).

Conclusion

This paper evaluated the physico-chemical parameters of tiger nut oil from three regions of Côte d'Ivoire. The analysis of physico-chemical parameters showed that the oils obtained from the three regions had similar yields and were of satisfactory quality. Tiger nut oils were rich in polyunsaturated fatty acids (83 - 88%), of which oleic acid was the most abundant (73 - 80%). High content of unsaturated fatty acids raises the possibility of including tiger nut oils in the human diet. Tiger nuts oils from the three regions exhibited a higher content of α -tocopherols and polyphenols and demonstrated greater oxidative indexes. In view of all these potentialities and qualities, tiger nut oils from the three regions presents significant opportunities for application across diverse industries, including food, nutraceuticals, animal feed, and cosmetics. Future investigations may focus on investigating the toxicological and antimicrobial effects of tiger nut oils before using them as supplements in food, nutraceutical and cosmetic industries.

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Conflict of interest

The authors declare no conflict of interest

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