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Physical parameters and physico-chemical properties of tiger nut *Cyperus esculentus* (yellow and black varieties) harvested in Bondoukou (North-East, Côte d'Ivoire).

Gnanda Paule Elise Kouame, Patrice Desire Yapi Assoi Yapi, Gbocho Serge Elvis Ekissi *, Hubert Kouassi Konan and Patrice Lucien Kouamé

Biocatalysis and Bioprocesses Laboratory, Food Science and Technology Department, University Nangui Abrogoua, Abidjan, Côte d'Ivoire.

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Abstract

The tiger nut *Cyperus esculentus* belongs to the family cyperaceous and is worldwide in distribution. Two varieties (yellow and black) obtained from Bondoukou area harvesting periods in Côte d'Ivoire were evaluated. Results showed wide variations between the two varieties. Means values for weight, length and diameter of two varieties ranged from 1.41±0.45-2.43±0.92g, 11±1.42-13.5±1.89mm, 8±1.11-9±1.38mm respectively. Major physicochemical properties are carbohydrates (63.93±1.43-63.27±1.10%), fat (23.41±1.75-22.54±1.41%), and fibers (7.68±0.2-8.57±0.06%). Caloric energy ranged from 422.07 to 431.27 kcal/100g. There was significant ($p<0.05$) difference between fat, carbohydrates, ash and fibers content of the flour samples. Minerals in abundance are potassium (12.37±0.01-16.57±0.01%), magnesium (0.69±0.00-4.1±0.07%) and phosphorus (2.63±0.01-5.05±0.01%). Ca, Na, Mn, Zn and Cu contents have lower than 1%. This work revealed that tiger nut flour is a potential source of food ingredient for supplementation and could be an excellent source of raw material for our growing food industries.

Keywords: Bondoukou; *Cyperus esculentus*; Varieties; Physical; Physico-chemical

1. Introduction

Tigernut is a perennial monocotyledous plant which has a tough erect fibrous root. The slender rhizomes of tigernut form weak runners above the ground level which develop smallsized tubers at the tip of the stem. Tigernut tubers can reach about six inches depth into the soil. The central erect stem of tigernut is usually covered by sheath of leaves [1]. There are three varieties of tigernut tubers easily identified based on the colour of the tubers. They are the yellow, brown and black variety. Only two of the varieties (yellow and brown) are commonly seen in most local markets in Côte d'Ivoire. The botanical name of tigernut is *Cyperus esculentus* L. It has other names depending on the tribe or region where tigernut tuber is cultivated and utilized. The Cyperaceae are monocotyledonous plants which include up to 4000 species worldwide [2]. Most of the Cyperaceae family is of very little economic value with the exception of Cyperus papyrus which is used in the manufacture of paper and Cyperus esculentus L (tiger nut) which is edible [3]. *C. esculentus* grows almost in all temperate, tropical and subtropical regions of the world like a weed. It's located in the Mediterranean region, Africa, India, North America, Mexico, Peru, and others [4]. Most growers of the tiger nut are the West African countries such as Nigeria, Senegal and Ghana. Also Spain is a good producer and exporter of Chufa which is popular there [5]. Tigernut (*Cyperus esculentus* L.) widely cultivates and consumed in many tropical and subtropical countries [6, 7]. Tubers are said to be aphrodisiac, carminative, diuretic, emmenagogue, stimulant, and tonic [8,9]. *Cyperus esculentus* is an edible grass plant which produces nut-like tubers known as tigernut [10]. Two major varieties (black and yellow) have been identified in many growing areas. The plant variety, location and period of planting have been

* Corresponding author: Ekissi Elvis Serge Gbocho
Biocatalysis and Bioprocesses Laboratory, Food Science and Technology Department, University Nangui Abrogoua, Abidjan, Côte d'Ivoire.

shown to have significant effects on physico-chemical properties of plant materials [11, 12]. The aim of this study was to determine the physical traits as well as the chemical characteristics of two tubers varieties grown in Côte d'Ivoire.

2. Material and methods

2.1. Tiger nuts

Seeds (*Cyperus esculentus* L.) varieties used in this research were provided from Bondoukou area (Côte d'Ivoire). Two major varieties of tigernut (black and yellow) were used. Tiger nuts were fully matured and freshly harvested. They were cleaned of adhering earth material, washed in clean potable water, and transported to the laboratory for analysis.

2.2. Flours preparation

For each batch, a sufficient quantity (one kilogram) of bean seeds was taken, rinsed four times with deionized water, dried in a ventilated oven at 55°C for 24 h, ground in an analytical flour mill and sieved with a sieve of 200 µm in diameter. The two bean (purple and white) flours obtained were stored in plastic containers and stored in the laboratory prior to use.

2.3. Physical measurements

The followings were the tools and equipment employed: Weights of the samples were determined by using a precision electronic balance reading to an accuracy of 0.01gm. To determine the average size of the seed, 100 seeds were randomly picked out of 120 seeds samples for Uyole-96 and their three principle dimensions (lengths, width, and thickness) were measured using a digital vernier caliper with an accuracy of 0.01 mm [13].

Hundred randomly selected seeds were used to measure length (L), breadth (B) and thickness (T), three principal dimensions which are in the three mutually perpendicular directions using A Vernier caliper reading 0.01 mm. 1000-seed weight was determined by counting one hundred seeds manually and weighing. The obtained values were then multiplied by a factor 10 to get 1000-seed weight [14]. Cooking time was determined according to the method [15]. The seeds were weighed and cooked at 65 °C with 550 ml of distilled water.

2.4. Physical analysis

2.4.1. Tuber weight

For each variety, a certain number of tubers were removed and weighed on a scale with a precision of 0.01 g counted to 100 tubers.

2.4.2. Tuber dimensions

Width and length measurements were made with digital calipers and average of the results was taken as mm.

2.5. Proximate analysis

Moisture content (on dry weigh basis) was determined on fresh sliced samples after oven drying at 105ºC for 24h according to [16]. Crude fat was determined exhaustively extracting sample of flours in a soxhlet apparatus using anhydrous hexan as solvent. Nitrogen was determined by the Kjeldahl method reported by [16] and crude protein content was subsequently calculated by multiplying the nitrogen content by a factor of 6.25. Ash content was determined by measurement of residues left after combustion in a furnace at 550ºC for 8 h [16]. Titratable acidity was made [17]. Fiber estimate was obtained from the loss in weight of dried residue following the digestion for fat-free samples with 1.25% each of sulfuric acid and sodium hydroxide solutions. pH was determined [16]. Carbohydrate were calculated using the following formulas [18]: Carbohydrates (Dry matter basis) = 100 - (% Moisture + % Proteins + % Lipids + % Ash + % Fibers). Energy were obtained by the summation of multiplied mean values for protein, fat and carbohydrate by their respective Atwater factors, 4, 9 and 4 [19].

Energy value (%) = (4 x %C) + (9 x %F) + (4 x %P) Where, C: Carbohydrates Content, F: Fibers Content, P : Proteins Content

2.6. Minerals analysis

The mineral elements were analyzed after wet-ashing using the scanning electron microscope (SEM) with variable pressure (SEM FEG Zeiss Supra 40 VP). This SEM is equipped with an X-ray detector (Oxford Instruments) connected to an energy diffusion spectrometry (EDS) microanalyzer platform (Inca Cool Dry, without liquid nitrogen). About 10 mg of the sample ash residue were applied evenly to a primed platform with double-sided adhesive carbon for analysis to measure the content of chemical elements, the device performs a measurement of the transition energy of the electrons from electronic clouds of the K, L and M series of atoms of the sample.

2.7. Determination of phosphorus

Phosphorus determination was carried out by the molybdenum blue method [20]. Two (2) grams of sample was dry-ashed and 5.0 ml of 5 M H2SO4 and 5 ml of 4% molybdate solution (25.0 g/l sodium molybdate in 5 ml H) added in a 100.0 ml volumetric flask. This was followed by the addition of 4 ml of 2% ascorbic acid. The mixture was then heated until a deep blue colour was developed. Deionised water was added to reach the 100 ml mark and the absorbance read at 655 nm using the atomic absorbance spectrophotometer (Perkin Elmer ASS, 5100 PC) against a blank. A standard curve was drawn by measuring absorbances at 655 nm of standard solutions containing 0.0 mg, 1.0 mg, 2.0 mg, 3.0 mg, 4.0 mg, and 5.0 mg of phosphorus in 100.0 ml deionised water. The phosphorus content of the snail sample was obtained from the standard curve.

2.8. Statistical analysis

All analyses were performed in triplicates. Results were expressed by means of ± SD. Statistical significance was established using Analysis of Variance (ANOVA) models to estimate the biochemical composition and physical parameters of tuber flour. Means were separated according to Duncan's multiple range analysis (p<0.05), with the help of the software Statistica (StatSoft Inc, Tulsa USA Headquarters).

3. Results and Discussion

3.1. Physical parameters

Physic parameters of tubers (*Cyperus esculentus*) varieties flours are presented in table 1. Results in Table 1 show physical parameters of *Cyperus esculentus* tubers. There were significant differences (p<0.05) in the indices measured between varieties. The mean value for length, width and weights tubers ranged from 0.98 to 1.31 cm, 0.90 to 1.19 cm, and 598 to 1044 mg, respectively [21]. The mean values for the two parameters (length, width) were 9.52mm, 8.16mm for fresh tiger nut and 9.14mm, 7.72mm for dried tiger nut respectively [22]. Physical parameters of studied tubers are higher than those [21, 22]. These values have a similar trend as reported by [23, 24]. These mentioned dimensions (length, width) are much important in the design of machines used in separation of agricultural product from undesirable materials and the development of sizing, grading, cleaning, sieving equipment, and storage facilities. These differences in indices of tubers from different planting periods, sites and varieties are similar to observations from other studies on plant materials [25, 26, 27] which has been attributed to differences in rainfall, climate, soil and crop variety [28]. Physical and mechanical properties are prerequisites in the design of suitable systems, machines, and structures for planting, harvesting, handling, processing, and storing of agro-products [29, 30]. This knowledge is important in the designing of machinery to harvest and in preparation of processing chain from grain to food. Knowledge of physical properties of agriculturally, nutritionally, and industrially valuated seed materials is imperative in designing the equipment for harvest, transport, storage, processing, cleaning, hulling, and milling [31,32].

Table 1 Physical parameters of *Cyperus esculentus* tubers (yellow and black varieties) from Bondoukou area (Côte d'Ivoire)

Parameters	Cyperus esculentus tubers (Varieties)	
	Yellow	Black
Weight (g)	1.41±0.45^{a}	2.43±0.92^{b}
Length (mm)	11±1.42^{a}	13.5±1.89b
Diameter (mm)	8±1.11^{a}	9±1.38^{a}

Values are mean ± standard deviation of triplicate measurements and those bearing different letter within a columns are significantly different at P<0.05

3.2. Proximate composition

Proximate composition of two tubers (*Cyperus esculentus*) is presented in table 2. For two varieties, significant differences (P < 0.05) were observed in some nutrient contents. The plant variety, location and period of planting have been shown to have significant effects on physico-chemical properties of plant materials [11, 12].

Moisture content of tubers ranged from 4.52±0.11 to 4.38±0.17% for yellow and black varieties beans respectively. Moisture content estimates directly the water content and indirectly the dry matter content of the sample. It is also an index of storage stability of the flour. Flour with moisture content less than 14 % can resist microbial growth and thus has better storability [33, 34]. The results show that the moisture contents range was within those [35] for barley grains which was 7.34 to 21.58 mg/100g and for fennel seed (*Foeniculum vulgare*) which were between 7.78% to 21.67 mg/100g [36]. However, moisture content is mainly dependent on drying and storage conditions, but not due to variety.

The carbohydrate was found to be the first component in these tubers (63.27±1.10-63.93±1.43 0%) as shown in Table 1. Tubers were also found to be a rich source of carbohydrates and being an excellent source of energy (422.07-.431.27 kcal/100g). The tuber mainly contains carbohydrates (more than 60%), which to a large extent consists of starch and dietary fiber. Carbohydrate provides a readily available energy source for oxidation metabolism and carbohydrate containing foods are vehicles for many important micronutrient. The two varieties studied are a importante source of carbohydrate compared to starch products with a carbohydrate base of more than 70% [37].

Fat yield from tiger nut obtained in this study, as shown in Table 2. Fat from tubers obtained in this study, was 22.54±1.41 (Yellow variety) to 23.41±1.75% (black variety) respectively. According to [38] fat (25%), are the second most dominant constituent in tubers nut, Fat values obtained in this study are lower than that of safflower oil (32%), and linseed oil (34%), both produced on commercial scale but much higher than soybean oil (20%) and corn oil (about 6%) [39]. Therefore, tiger nut, with its inherent nutritional and therapeutic advantage, could serve as good alternative to imported vegetable oils in food products. Tiger nut fat has composition similar to olives and a rich mineral content. Tiger nut oil contributes to the reduction of cholesterol, it reduces the risk of coronary heart diseases and atherosclerosis .Tuber nut fat is gold brown in color and has a rich, nutty taste [40, 41, 42]. Tiger nut fat is reported to be an; antioxidant, anti-arthritic, anti-inflammatory, analgesic, antibacterial, atherosclerotic and anticonvulsant [43].

Table 2 Physicochemical parameters of *Cyperus esculentus* tubers flours (yellow and black varieties) from Bondoukou area in Côte d'Ivoire

Parameters (%)	***Cyperus esculentus* tubers Varieties (Flours)**	
	Yellow	**Black**
Moisture	4.52±0.11^a	4.38±0.17^a
Protein	2.91±0.01^a	3.09±0.01^a
Fat	23.41±1.75^a	22.54±1.41^b
Carbohydrates	63.93±1.43^a	63.27±1.10^b
Ash	2.08±0.03^a	2.52±0.40^b
Fibers	7.68±0,2^a	8.57±0.06^b
pH	6.80±0.01^a	6.94±0.01^a
Titratable Acidity	0.013±0.0^{0a}	0.013±0.00^a
Energy Value (KCal/100g)	431.27^a	422.07^b

Values are mean ± standard deviation of triplicate measurements and those bearing different letter within a columns are significantly different at P<0.05

Tuber nut was observed to be high in dietary fiber content (7.68±0.2-8.57±0.06 %), which could be effective in the treatment and prevention of many diseases including colon cancer, coronary hearth diseases, obesity, diabetics and gastro intestinal disorders [44, 45], and would also rank well with other whole grains or starchy roots, such as potatoes, mature leguminous seeds, nuts and fruits [46] as a source of fiber in foods. [47] Reported a fiber content of 6.5%, which is lower than that obtained in this study.

Protein content (2.91±0.01-3.09±0.01%) was higher to the values of [47, 48] who reported protein content to be 1.56 and 1.32 respectively; this could be due to difference in varieties. The generally low levels of crude protein would require dietary supplementation of animal protein or complementary protein from cereals and legumes, particularly in diets targeted to the target population of kwashiorkor (growing children and pregnant women) [49]. Tuber nuts energy ranged to 422.07 (black variety) to 431.27 (yellow variety). Energy is essential for rest, activity and growth. Carbohydrate, protein and fat are three components which provide energy [50]. The tiger nut is very nutritive and serves as a good source of energy [51].

3.3. Mineral composition

The mineral content of tiger nut flour is presented in table 3. The mineral profile of tubers flour shows a flour rich in macroelements (Potassium, Magnesium and Phosphorus) and could be useful for children, pregnant women or athletes [52]. High levels of these minerals are thought to be associated with the diet of these snails [53, 54] also reported in their study that the potassium content of tiger nuts was the most dominant mineral. The high quantity of minerals in tiger nut tubers was potassium, phosphor, and magnesium which were 267.18 mg/100g, 158.86 mg/100g, 118.14 mg/100g, respectively [55].

The potassium content of the black variety (16.57±0.01%) was higher than the yellow variety (12.37±0.01%). Potassium is needed for the regulation of fluid, muscle control and normal nerve function. Potassium is the principal intracellular cation and in conjunction with sodium plays a very important role in the regulation of water and electrolyte balance as well as acid-base balance in the body [56]. Besides, potassium lowers blood pressure, when it is consumed in our foods [57, 58]. Potassium influences the contractility of smooth, skeletal, and cardiac muscles and profoundly affects the excitability of nervous tissue [59, 60]. Thus, the bioavailability of potassium would result in protection against increased blood pressure and other cardiovascular risks [61]. High potassium to low sodium ration of tiger nuts therefore, may be imperative in diet formulations for patients with high blood pressure and edema as well [62].

Phosphorus content of black variety (5.05±0.01%) was higher than the yellow variety (2.63±0.01%). Phosphorus has more functions than any other mineral element in the body. It forms a complex with calcium that lends rigidity to bones and teeth [63]. In the same way, these minerals would be precursors of the synthesis of amino acids which would be at the base of the installation of the organs of the snails [64]. Thus, the bioavailability of calcium would result in protection against increased blood pressure and other cardiovascular risks [61]. Phosphorus and calcium, as basic elements in tiger nut tubers, constitute the bulk of the mineral substance of the bones and teeth. It has an impact in the formation of ATP, a vitality compound imperative for "activating" glucose, unsaturated fats, etc. [45].

Table 3 Mineral composition of yellow and black varieties from *Cyperus esculentus* tubers from areas Bondoukou in Côte d'Ivoire

Parameters (%)	Varieties	
	Yellow	Black
Calcium	0.13±0.01[a]	0.23±0.02[a]
Phosphorus	2.63±0.01[a]	5.05±0.01[b]
Magnesium	4.1±0.07[a]	0.69±0.00[b]
Potassium	12.37±0.01[a]	16.57±0.01[b]
Sodium	0.06±0.00[a]	0.04±0.00[a]
Manganese	0.01±0.00[a]	ND
Zinc	0.04±0.00[a]	0.09±0.00[b]
Copper	0.04±0.00[a]	0.04±0.00[a]
Iron	0.58±0.00[b]	0.56 ± 0.00[a]

Values are mean ± standard deviation of triplicate measurements and those bearing different letter within a columns are significantly different at P<0.05

The magnesium content of the yellow variety (4.1±0.07%) was higher than the black variety (0.69±0.00%). Magnesium provides bone strength, aids enzyme, nerve and heart functions [62].

The calcium content of this work was lower (0.13±0.01%-0.13±0.01%) than the values reported by [54]. Tiger nut tubers are benefit for bones, tissue repair, muscles, and the bloodstream and body development due to its richness in phosphorus, potassium, calcium, magnesium [66]. Calcium aids in the formation of bones and plays a role in maintaining the working of the heart and muscles [67]. According to [68], some researchers reported that tigernut tubers contains low quantity of calcium, iron, zinc and copper but has a high content of magnesium,, phosphorus, potassium.

4. Conclusion

Due to the attempts to change many sources of alimentary products such as ash, gluten, protein, sugar, etc., by other healthy sources, tiger nut is one of the best solutions. Its high content of nutrients and minerals, makes it an important alimentary plant.

Tiger nut tubers are a rich source of fat and contains moderate amount of protein. It is also a rich source of fiber and carbohydrates. Mineral content differs significantly from one variety to another and the most dominant are potassium, magnesium and phosphorus. The research results can be used by investigators and food businesses to develop recipes for processed bean foods, including fortified products.

Compliance with ethical standards

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Disclosure of conflict of interest

Kouame GPE, Yapi AYDP, Ekissi ESG, Konan KH, Kouame LP are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as constituting a conflict of interest.

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