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MORPHOLOGICAL, PHYSICOCHEMICAL, NUTRITIONAL, TECHNOLOGICAL AND HEALTH CHARACTERIZATION OF TUBERS ABOUT THREE NUTSEDGE (CYPERUS ESCULENTUS) CULTIVARS PRODUCED AND MARKETED IN BENIN

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Abstract

The edible nutsedge is an weedy plant species whose tuberous roots are comparable to tubers from conventional agriculture. The present study aims to characterize the tubers of three nutsedge cultivars in terms of morphology, technology, nutrition and health. The morphological data reveal average diameter and length of the tubers of the black cultivar greater than those of the brown (twice) and yellow (once) tubers. In addition, the mass of black tubers is 10 times that of brown tubers and 2.5 times that of yellow ones. The black cultivar is on the other hand the least acidic (6.22 ± 0.01) compared to the brown cultivar (5.37 ± 0.01) which is more acidic. Considering the technological parameters, the cultivars are similar according to the tuber densities before and after soaking; CH; IH; CG and IG. Analysis of the nutritional potential of the yellow cultivar reveals high protein (4.04 ± 0.03%) and ash (2.7± 0.02%) contents while the highest fat content is contained in the brown nutsedge (21.10 ± 0.12%). The yellow cultivar is richer in Vitamins A and C with 0.62 ± 0.01 mg/L and 0.14%. The same is true for minerals K (8569.01 ± 175 mg/kg); Ca (1333.28 ± 53.4 mg/kg) and P (2000 ± 28.3 mg/kg). The brown cultivar has the highest levels of Iron (136.40 ± 5.30 mg/Kg), Sodium (2217.02 ± 104.2 mg/Kg) although the greatest proportion of Zinc is contained in the cultivar black (185.35 ± 0.28 mg/Kg). FAN are concentrated in the black cultivar with a preponderant content of oxalic acid compared to those of the brown (2 times) and yellow (1.5 times) cultivars. Furthermore, the health assessment presents trace amounts of heavy metals in the three cultivars. Keywords: Yellow nutsedge; cultivar; technological parameters; nutritional potential; heavy metals

Keywords : edible nutsedge; cultivar; technological parameters; nutritional potential;heavy metals

Résumé

Le souchet comestible est une espèce végétale adventice dont les racines tubéreuses sont comparables aux tubercules issus des agricultures conventionnelles. La présente étude vise à caractériser les tubercules de trois cultivars de souchet aux plans morphologique, technologique, nutritionnel, et sanitaire. Les données morphologiques révèlent des diamètre et

longueur moyens des tubercules du cultivar noir supérieurs à ceux des tubercules bruns (2 fois) et jaune (1 fois). De plus, la masse des tubercules noirs est 10 fois supérieure à celle des tubercules bruns et 2,5 fois celle des jaunes. Le cultivar noir est par contre le moins acide (6,22 ± 0,01) en comparaison du cultivar brun (5,37 ± 0,01) plus acide. Considérant les paramètres technologiques, les cultivars sont semblables suivant les densités des tubercules avant et après trempage ; CH ; IH ; CG et IG. L'analyse du potentiel nutritionnel du cultivar jaune révèle les fortes teneurs en protéines (4,04 ± 0,03 %) et cendres (2,7± 0,02%) alors que la plus forte teneur en matières grasse est contenue dans le souchet brun (21,10 ± 0, 12%). Le cultivar jaune est plus riche en Vitamines A et C avec 0,62 ± 0,01 mg/L et 0,14%. Il en est de même pour les minéraux K (8569,01 ± 175 mg/kg) ; Ca (1333,28 ± 53,4 mg/kg) et P (2000 ± 28,3 mg/kg). Le cultivar brun détient les plus fortes teneurs en Fer (136,40 ± 5,30 mg/Kg), Sodium (2217,02 ± 104,2 mg/Kg) bien que la plus grande proportion de Zinc, soit contenue dans le cultivar noir (185,35 ± 0,28 mg/Kg). Les FAN sont concentrés dans le cultivar noir avec une teneur prépondérante en acide oxalique à celles des cultivars brun (2 fois) et jaune (1,5 fois). Par ailleurs l'évaluation sanitaire présente les métaux lourds en trace dans les trois cultivars.

Mots clés : Souchet comestible ; cultivar ; paramètres technologiques ; potentiel nutritionnel ; métaux lourds

Introduction

Weeds are often cited as one of the major problems in conventional or organic field crop systems. These weeds are, unconventional agriculture, managed preventively by agronomic means implemented in the cultivation system but above all in a curative or preventive manner by the use of chemical herbicides (Morison et al., 2012). However, some of these weeds are edible and can compete with conventional crops. Among these weed plants is the edible nutgrass belonging botanically to the order Cyperales, family Cyperaceae, subfamily Scirpoideae, tribe Scirpeae, subtribe Cyperinae, genus Cyperus. The species is C. esculentus L. produces tuberous seeds called ground tiger nuts (Odoemelan, 2003; Belewu et al., 2007). In Africa, tigernut is cultivated in the North and West, particularly in Ghana, Nigeria, Niger, Burkina Faso, Mali and Ivory Coast (Defelice, 2002). In Benin, tigernut production is carried out on a small scale by farmers for whom tigernut constitutes a significant source of income. Indeed, tiger nuts are grown in Benin mainly in the municipalities of Matéri (Annual Report 2011-2012 CeCPA Matéri, 2015) and Boukoumbé (CCPA, 2005). Production in the commune of Boukoumbé is estimated at 38 tonnes for an area of 71 ha at the end of the 2002-2003 campaign. In Matéri in the north of the country, production is estimated at 11 tonnes over an area of 19 ha (Annual Report 2011-2012 CeCPA Matéri, 2015). The tubers produced by this plant have a better nutritional value than those of cassava tubers (Maieves et al., 2012), sweet potatoes (Olayiwola et al., 2009; Lai et al., 2011), yams (Abara, 2011), fines (Venkatachalam and Sathe, 2006) and nuts (Erdogan and Aygun, 2005; Venkatachalam and Sathe, 2006; Freitas and Naves, 2010; Ros, 2010). As a result, the tubers of nutsedge plants have a better nutritional value than the roots and tubers which constitute in the world, after cereals, the second group of food crops, in order of economic importance and in area sown. The tubers have a pleasant flavor, so they are harvested for consumption (Adam Issah, 2019). But the storage conditions sufficiently influence the longevity of the tubers. Indeed, the lifespan of the tubers is marked

by the size of the tubers. Thus, tubers of greater weight have a longer half-life than those of lower weight (Kelly et al., 2002). In addition, the lack of knowledge of the nutritional characteristics of tiger nut tubers limits its valorization. Variability in nutritional characteristics of tubers was observed. Indeed, tubers have varying contents of proteins (3.98 to 9.70%), fat (24.00 to 35.43%), carbohydrates (22.08 and 75.88%) and energy value (1511 to 1754.98 kJ / 100g (Oladele and Aina, 2007; Salau et al., 2012). This variability can be due to many factors including the type of cultivar. Indeed, there are different types of nutsedge based on shape and size, as well as color Oladele and Aina (2007) mentioned three different types of nutgrass based on the color of the rhizomes (yellow, brown and black). size (mainly size), there are also three types of nutsedge: mini (6-8 mm), standard (8-12 mm) and large (> 12 mm) (Dakogre, 2008). large nutsedges, Pascual et al. (2000) mentioned three subcategories namely: 'Gegant Africana' (GA) which is characterized by its large size (length 17.3 mm). 1.09g; 'Llargueta Alboraia' (LA) produces oval tubers (length 15.2 mm). It yields more than the other two cultivars 18,525 t/ha and 'Ametlla Bonrepos' (AB) produces spherical tubers (length 12.4 mm). It gives a good tuber yield of 15,977 t/ha. In terms of general yield, regardless of the type of cultivar, the yield of nutsedge is between 0.8 to 14 t/ha. In view of this observation, the type of cultivar could influence the nutritional composition. Thus, the present study aims to reveal the physicochemical, technological, nutritional and health characteristics of the different tigernut cultivars produced in Benin in order to consider the development of the main areas of valorization with a view to improving food and nutritional coverage. mainly in infants, young children and pregnant women.

Material and methods

Material

The plant material consists of the tubers of three cultivars of edible nutsedge (Cyperus esculentus), namely: brown or brown tubers, rounded in shape; yellow tubers, rounded shape and black tubers, elliptical shape (Plate 1). These nutsedge tubers are harvested at the production sites at maturity from the producers during surveys in Natta in the commune of Boukoumbé in ATDA 3. The tubers, after harvest, were washed in tap water, dried for one week at room temperature. The tubers thus obtained and the flour derived from these tubers are used for their technological and nutritional characterization.



Picture 1 Picture 2 Picture 3

A : browns cultivar tubers, rounded shape ; B : Yellows tubers, rounded shape ; C : Blacks tubers, elliptical shape

Study framework

The sampling site (Figure 1) is at Natta (Pink color) in the commune of Boukoumbé. The commune of Boukombé is located in the department of Atacora, in the northwest of Benin. Boukombé is located fifty-four (54) km from Natitingou, capital of the department and approximately six hundred (600) km from Cotonou. It is limited by Tanguiéta to the North-East, Cobly to the North-West, Natitingou to the South-East, to the East by Toucountouna and to the West by the Republic of Togo. With an area of 1,036 km2, the commune of Boukombé has 7 districts and 93 villages according to the new territorial division. It also presents particular geomorphological and natural characteristics. It benefits from a dry Sudano-Guinean climate including a rainy season of five (5) months (mid-May to mid-October) and a dry season of seven (7) months (mid-October to mid-May).

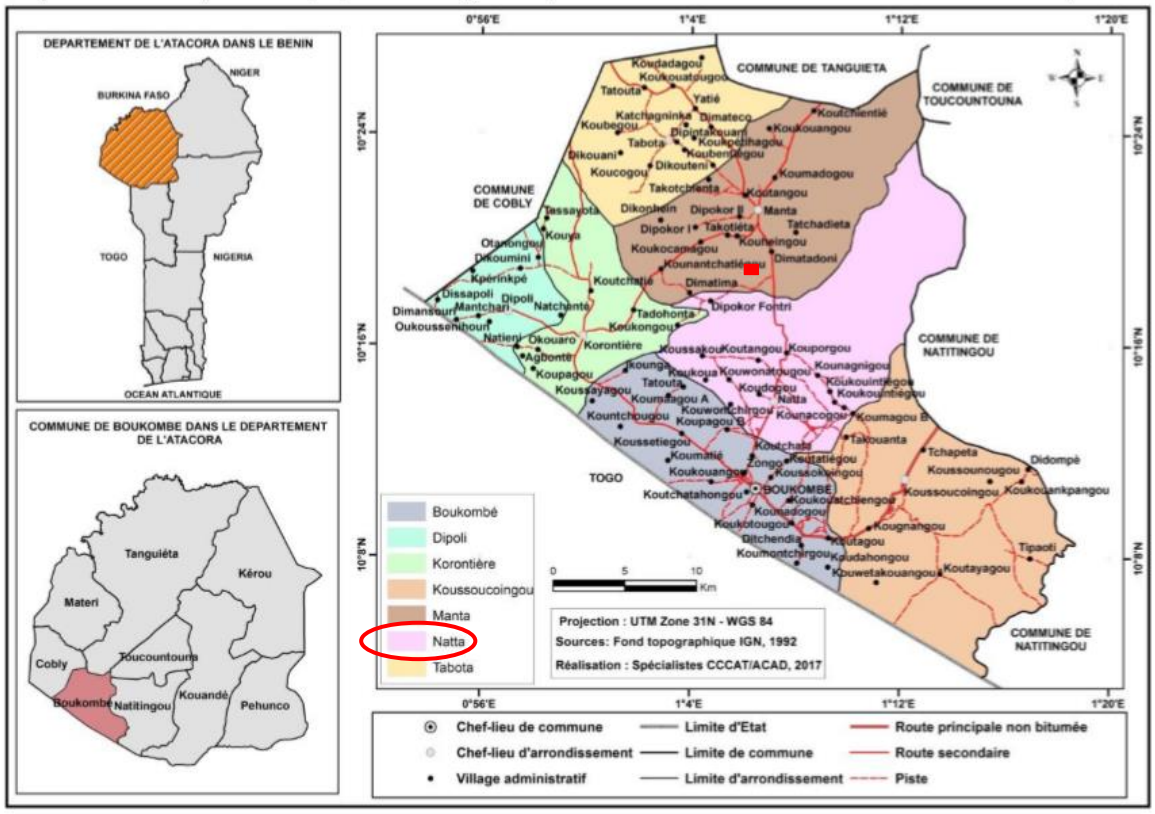


Figure 1: Administrative map of the commune of Boukoumbé

Methods

Sampling conditions

Samples were purchased from growers at harvest. They were kept in a bag to limit biochemical and microbiological changes and transported to the laboratory to undergo various analyses.

Sampling technique

Convenient sampling technique is used for data collection.

Technological characterization of the tubers

Physico-chemical and technological properties of nutsedge tubers

The technological characterization of the tubers of the three nutsedge cultivars was carried out through the determination of morphological characteristics (length, diameter); chemical (pH; titratable acidity (AOAC,2012)); the mass; the density ; hydration capacity; hydration index; swelling capacity and swelling index.

The physical characteristics of the tubers were determined according to Williams et al. (1986), with modifications. Fifty tubers are counted and weighed. The size distribution of nutsedge tubers was assessed using a screen with foci of 5-9mm in diameter. The diameter and length of 10 randomly selected tubers are measured using a caliper. Fifty nutsedge tubers are transferred to a 100 ml test tube and 50 ml of demineralized water. Tuber volume (ml per tuber) was recorded as (total volume-50)/50. Density was recorded in g/ml calculated from the weight and volume of 50 tubers. The fifty tubers were transferred to a 125 ml Erlenmeyer flask and 50 ml of water. The vial was closed tightly and left for 24 h at room temperature. The tubers were then drained, excess water was removed with a paper towel, and the swollen tubers were weighed again. Hydration capacity (HC, g water per tuber) was calculated as (weight after soaking-weight before soaking)/50. The hydration index (HI) per tuber is calculated by dividing the hydration capacity by the original weight per tuber. Cooking time is directly related to HC but not to HI. After weighing the soaked tubers, they were transferred to a measuring cylinder of 100 ml and 50 ml of water. Swelling capacity (SC, ml per tuber) was calculated as (volume after soaking-volume before soaking)/50. The swelling index (SI) per tuber is given before soaking).

Nutritional characterization of tubers

Preparation of samples

The nutsedge tubers (Cypérus esculentus L) obtained on the production sites in Natta in the commune of Boukoumbé, were sorted to remove stones, pebbles, dirt, rotten stems and broken tubers before being cleaned at water to remove adhering soil. The cleaned tubers were dried in an oven at 60°C for five hours before being transported to various laboratories for the various analyses. The analyzes focused on bromatology, nutritional and antinutritional dosages as well as heavy metals.

Bromatological characterization

Bromatological characterization is revealed by the determination of antinutritional factors (phytates, tannins, and phytic acids), proximal composition (lipids, proteins, carbohydrates, dry matter, reducing sugars, energy, ash; vitamin A and vitamin C). Antinutritional factors are: tannins, oxalates and phytates.

The nutritional potential of tubers is assessed by measuring proteins (Kjeldahl method), lipids (AOAC, 2012), total sugars (AOAC, 2012), reducing sugars (AACC 80-60 method (AACC, 2012), total ash (A OAC, 1993), vitamins A and C (AACC, 2012) and mineral salts and trace elements (K, Na, Mg, Ca, Zn, Fe) (ISO/TC 27/SC 5 standard).

Determination of tannins

For tannin determination, 10 ml of 70% aqueous acetone was added to 200 mg of finely ground sample in a bottle and properly covered. The vial was placed in an ice bath shaker for 2 h at 30°C. The solution was then centrifuged and the supernatant stored on ice. From the supernatant, 0.2 ml was pipetted into 0.8 ml of distilled water. A standard solution of tannic acid was prepared. Folin reagent (0.5 ml) was added to the sample and standard followed by 2.5 ml of 20% Na2CO3.The solutions were vortexed and allowed to incubate for 40 minutes at temperature ambient, after which the absorbance was read at 725 nm. The tannin concentration in the sample was estimated from the standard tannic acid curve (Makkar et *al*., 1996).

Oxalate determination

The titration method described by Day and Underwood (Day, 1986) was used to determine the oxalate content. One gram of the sample was weighed into a 100 ml conical flask where 75 ml of 3N H2DONC4 was added and stirred intermittently with a magnetic stirrer for 1 h. It was then filtered using Whatman No.1 filter paper. From the filtrate, 25 ml was taken and titrated hot (80-90°C) against 0.1N KMnO4 solution until a slight pink color persisted for at least 30 seconds.

Determination of phytate

The phytate content of the flours was determined by the Maga method [13]. Two grams (2 g) of each finely ground flour sample was soaked in 20 ml of 0.2 N HCl and filtered. After filtration, 0.5 ml of the filtrate was mixed with 1 ml of ferric ammonium sulfate solution in a test tube, boiled for 30 min in a water bath, cooled in ice for 15 min and centrifuged at 3000 xg for 15 min. One milliliter of the supernatant was mixed with 1.5 ml of 2,2-pyridine Solution and the absorbance measured in a spectrophotometer at 519 nm. Phytic acid concentration was obtained by extrapolation from a standard curve using a standard phytic acid solution.

Evaluate the bioconcentration of heavy metals (Pb, Cd, Ni, As)

Mineralization is carried out by the method proposed by Pauwels et al. (1992). For the determination of metals, a quantity of 3g of each sample is placed in Teflon tubes to which 6 ml of nitric acid (68%) will be added then closed using watch glasses. After solubilization, the tubes were placed in a sand bath gradually heated to a temperature reaching 130°C until the acid had completely evaporated. The pellets obtained will be dissolved hot with distilled water. After cooling, each solution resulting from the acid attack will be measured in a 25 ml flask. After homogenization, the solution will be filtered using filter paper (0.45 µm). At the same time, two control solutions (6 ml of 68% HNO3) will be prepared under the same conditions. The determination of heavy metals is carried out using a flame atomic absorption spectrometer of the Thermo Electron Corporation S Series AA Spectrometer type.

Statistical analyzes

All analyzes were repeated twice. The results of the three samples are expressed as mean ± standard deviation. The values of the different tests were used to make two-by-two

comparisons using the Fisher method with a confidence level of 95%. Subsequently, a principal component analysis was carried out in order to associate the best characteristics with the different varieties of nutsedge considered.

Results and discussion

Assessment of physicochemical and technological characteristics of tiger nuts tubers

Physical characteristics of nutsedge tubers

Table 1 shows the distribution of nutsedge tubers according to some physical characteristics, namely: density (g/ml); hydration capacity; hydration index; swelling capacity; swelling index; the diameter and length.

Tableau 1: Summary of phytochemical and technological characteristics of tubers

	Physical characteristics						**Chemical characteristics**			**Technological characteristics**					
Sample	L	D	Correlation Coefficient (L/D)	Sphéri City (L/D)	Masse of 1000 grains	Volumic masse	Dry Matter % (P=0,256)	pH (P=0,000)	Titrateble acidity (%) (P=0,001)	Density before soaking 1 (g/ml)	Densité after soaking 2 (g/ml)	HC	HI	SC	SI
CN	11,77 ±2,64	1,52± 0,29	0,674212	7,74	1300,0±14 ,1a	1kg/0,08862 ± 0,0008[c] m³ 1kg/0,88621 L± 0,008	89,40 ± 1,56	6,2200 ± 0,0141[a]	0,0079 ± 0,01 [c]	1,10±0,04	1,09±0,02	0,15±0,0 9	0,13± 0,09	0,16± 0,10	1,15± 0,10
CB	6,64± 1,11	0,79± 0,14	0,650096	8,4	128,00 ±4,24 [c]	1kg/0,0853 ± 0,0015[a] m³ 1kg/0,8533 L±0,015	88,70 ± 0,00	5,3700 ± 0,0141[c]	0,01370± 0,00[a]	1,13±0,09	1,14±0,06	0,08±0,0 1	0,51± 0,09	0,07± 0,01	1,50± 0,14
CJ	9,25± 1,50	1,13± 0,19	0,493965	8,18	490,50±3, 54 [b]	1kg/0,08773± 0,0012[b] m3 1kg/0,87732 L±0,012	90,60 ± 0,283 [a]	5,940 ±0,000[b]	0,01130 ± 0,00 [b]	1,16±0,28	1,35±0,46	0,17±0,0 7	0,34± 0,14	0,16± 0,06	1,35± 0,36

CB: Brown Tigernut; CJ: Yellow Tigernut; CN: Black Tiger Nut

Density 1: Density of the tubers before soaking; Density 2: Density of tubers after soaking; HC: Hydration Capacity; HI: Hydration Index; SC: Swelling Capacity; SI: Swelling Index; D: Diameter; Length: Length; CC: Correlation Coefficient

Table 1 summarizes the physical, chemical and technological characteristics of three cultivars of edible nutsedge, namely: the black, yellow and brown cultivars. Appreciation of the values derived from physical traits makes it possible to deduce that the average diameter and length of black nutsedge tubers are greater than those of brown (~2 times) and yellow (1 times) tubers respectively. This gives the brown tubers a more pronounced sphericity than the black and yellow tubers which have a more elongated shape although the strongest correlation between these two metric parameters is identified on the samples of the black cultivar, just ahead of the brown ones. Beyond the metric measurements which have a certain statistical similarity, the tubers of the three cultivars are different from the point of view of density and mass of 1000 grains. In fact, the mass of 1000 grains of black tubers is 10 times greater than that of brown tubers and 2.5 times that of yellow ones.

The evaluation of the mass of the 1000 grains reveals that the black nutsedge tubers are the heaviest (1300.0 g ±14.1) while the light weight is held by the brown tubers (128.00 g ±4.24). Conversely, the tubers of the black cultivar recorded the greatest density (1kg/0.08862 ± 0.0008c m³/1kg/0.88621 L± 0.008) while the brown ones, less bulky, minimized the values (1kg/0.0853 ±0.0015a m³/1kg/0.8533 L±0.015).

The results from the chemical analysis of nutsedge tubers show that they are poor in water with statistically invariable water percentages. The acidity of the tubers, however, varies from one cultivar to another. The brown cultivar has more acidic tubers (5.3700 ± 0.014) while the least acidic is the black (6.2200 ± 0.0141).

Statistical analysis in one-way ANOVA controlled at a significance level $\alpha = 0.05$ for each parameter depending on the cultivar revealed a similarity of the cultivars considering each parameter studied through two forms of pairwise comparisons of Tukey and of Fisher with a confidence level of 95%. Thus, the tubers of the three cultivars studied present statistically similar values for tuber density before soaking; Density of tubers after soaking; hydration capacity; the Hydration Index; swelling capacity and swelling index.

Nutritional value of the tubers

The nutritional value of the three types of tiger nuts cultivars was highlighted by their content of fat, proteins, total sugars, reducing sugars, vitamins A and C in total ash (table 44) and minerals and trace amounts. -elements and their energy value (table 45).

Table 2: Energy value and proximal and vitamin A and C composition of tigernut tubers

	CB	CJ	CN	Moyenne ± EC
Energy (kcal)	449.8 ± 14.3	452.14 ± 0.48	440.59 ± 9.19	447.51 ± 3.00
Fat (%)	21.10 ± 0.17^{a}	20.50 ± 0.42^{a}	16.99 ± 0.02^{b}	19.53 ± 0.20
Protéins (%)	3.65 ± 0.06^{b}	4.04 ± 0.014^{a}	3.69 ± 0.08^{b}	3.79 ± 0.05
Carbohydrates (%)	61.34 ± 3.25	62.87 ± 1.09	68.24 ± 2.17	64.15 ± 2.17
Reducing sugars (%)	0.80 ± 0.02	0.94 ± 0.20	0.63 ± 0.00	0.79 ± 0.07
Ashe (%)	1.9 ± 0.00^{b}	2.7± 0.028^{a}	2.5 ± 0.14^{a}	2.37 ± 0.01
Vitamin C (mg/L)	0.48 ± 0.01^{b}	0.62 ± 0.01^{a}	0.5 ± 0.01^{b}	0.53 ± 0.01
Reducing sugars (%)	0.041 ± 0.00^{b}	0.14±0.00^{a}	0.015 ± 0.00^{c}	0.19 ± 0.00

For N= 2 repetitions. Values in the same column that do not share the same letters are significantly different at the 5% threshold. CB: Brown Tigernut; CJ: Yellow Tigernut; CN: Black Tiger Nut

No significant difference was observed (P>0.5) in the energy level, total carbohydrate and reducing sugar contents of the three cultivars with respective means of 447.51 kcal, 64.15% and 0 .79% (Table 2). On the other hand, the fat content of black nutsedge is significantly lower (P<0.5) than that of brown and yellow nutsedges with values between 16.99 and 21.10%. Yellow nutsedge had the highest protein content (4.04%) compared to brown and black nutsedges. The vitamin A composition was significantly (P<0.5) different at the three cultivars of nutsedge and the high value (0.14%) was obtained at the yellow nutsedge and the lowest value (0.015%) at the level black nutsedge. Yellow nutsedge had the highest vitamin C content (0.62 mg/g) compared to brown and black nutsedge tubers (Table 2). Table 3 reveals the content of ash and mineral salts and trace elements of the three nutsedge cultivars. The ash content of black and yellow nutsedge tubers was similar (2.5 to 2.7%) and significantly higher (P<0.5) than that of brown nutsedge which is 1.9%.

Trace element composition

The individual mineral composition of nutsedge shows that it is an important source of mineral salts with some variability within cultivars.

Table 3: Content of ash and mineral salts and trace elements

	CB	CJ	CN	Moyenne
Mg	840,97 ± 11,51	891,37 ± 19,8	964,31 ± 14,7	898,88 ± 15,34
Fe	136,40^{a} ± 5,30	111,67^{b} ± 1,65	113,34 ± 0,1^{b}	120,47 ± 5,89
Na	2217,02 ± 104,2^{a}	1087,82 ± 37,1^{b}	1194,26 ± 86,0^{b}	1499,7 ± 93,05
K	6543,31 ± 416^{b}	8569,01 ± 175^{a}	7812,26 ± 77,3^{a}	7641,53 ± 222,77
Ca	1194,37 ± 32,7^{b}	1333,28 ± 53,4^{a,b}	1464,78 ± 71,2 ^{a}	1330,81 ± 52,43
Zn	13,03 ± 0,078^{c}	17,68 ± 0,58^{b}	185,35 ± 0,28^{a}	72,02 ± 0,55
P	1900 ± 70,7^{a}	2000 ± 28,3 ^{a}	1350 ± 56,6^{b}	1750 ± 51,87
Cu	6,62 ± 1,61	4,13 ± 0,42	4,03± 0,54	3,93 ± 086

CB: Brown Tigernut; CJ: Yellow Tigernut; CN: Black Tigernut

For N= 2 repetitions. Values in the same column that do not share the same letters are significantly different at the 5% threshold.

. When reading Tables 3, we see that the tubers of the three nutsedge cultivars present, considering two-by-two comparisons with the Tukey method and a confidence level of 95%, statistically different values for minerals such as sodium (Na); potassium (K); calcium (Ca), zinc (Zn) and phosphorus (P). Indeed, the content of Magnesium (Mg), Iron (Fe) and Copper (Cu) were similar (P>0.5) in the three cultivars with respective averages of 898.88mg/g, 20.47mg/g. g and 4.93mg/g. However, yellow nutsedge cultivars have the highest Na contents (1087.82 ± 21.21 mg/kg); K (8569.01 ± 123.84 mg/kg); Ca (1333.28 ± 37.75 mg/kg) and P (2000 ± 0 mg/kg) except Zn (185.35 ± 0.19) which is contained in high proportion by the tubers

of black nutsedge cultivars. Brown nutsedge cultivars hold the highest contents respectively for minerals such as Iron (136.40a ± 5.30), Sodium (2217.02 ± 104.2a) while the greatest proportion of Zinc is held by black nutsedge cultivars (185.35 ± 0.28). When it comes to minerals such as energy and copper, the values obtained are statistically not different.

Characteristics of antinutritional factors and molar ratios

Composition of antinutritional factors

The bioavailability of the nutritional potential of tiger nut has a connotation with the different proportions of anti-nutritional factors inside the tubers (table 5).

Table 4: Antinutritional factors

	Oxalic acid (%)	Tannin (%)	Phytic acid (%)	ANF (%)
CB	1,12±0,05^{b}	0,27±0,12^{a}	0,14±0,08^{a}	1,53±0,25^{c}
CJ	1,44±0,14^{b}	0,38±0,09^{a}	0,30±0,02^{a}	2,12±0,25^{b}
CN	2,22±0,021^{a}	0,45±0,04^{a}	0,19±0,01^{a}	2,86±0,07^{a}

FAN: Antinutritional factors; CB: Brown nutsedge tubers, CJ: Yellow nutsedge tubers, CN: Black nutsedge tubers

Four antinutritional parameters are evaluated on the tubers of the three nutsedge cultivars taken into account in this work. Overall antinutritional factors, oxalic acid, tannins and phytic acid are the parameters taken into account. The values obtained for these parameters are presented according to each cultivar (Table 5). Looking at the information, significant variations emerge for the overall antinutritional factor parameters and oxalates. Thus, we see a significant difference for the first from one cultivar to another with respectively 1.53 ± 0.17% (brown cultivar); 2.12 ± 0.07% (yellow cultivar) and 2.86 ± 0.12% (black cultivar). The black cultivar contains 2.22 ± 0.021% oxalic acid, much higher than those held by the yellow and brown cultivars which share statistically identical values. Regarding the other two remaining parameters, the values obtained are statistically identical for each parameter and from one cultivar to another.

Table 5: Molar ratios

	T/p	Phy/Fe	Phy/ Zn	Phy/Mg	Phy/Ca	Phy/P	O/ca	O/ Mg	Phy × Ca/Zn
CB	0,07	10,26	107,44	1,66	1,17	0,74	9,37	13,32	12,83
CJ	0,09	26,94	169,68	3,37	2,25	1,5	10,8	16,15	22,62
CN	0,12	16,76	10,25	1,97	1,29	1,41	15,16	23,02	1,5

T : Tanin ; P : Protéines; Fe : Fer ; Phy : Phutates ; Zn : Zinc ; Mg : Magnésium ; Ca : Calcium ; O : Oxalates

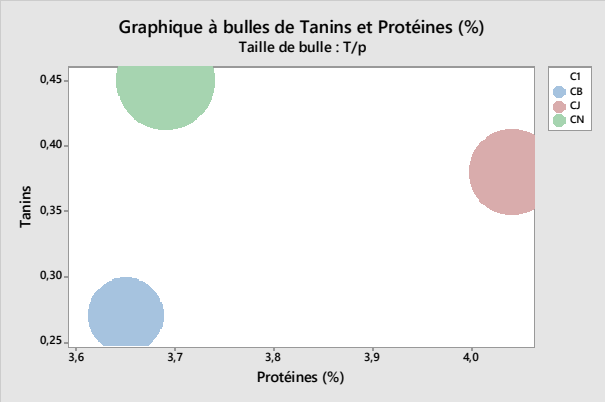


Figure 2 : Variation of molar ratio T/P

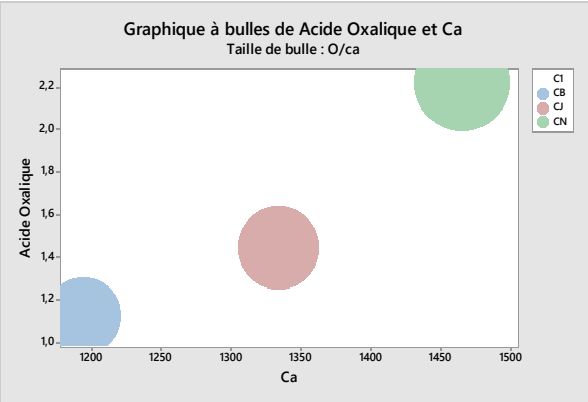


Figure 3 : Variation of molar ratio O/Ca

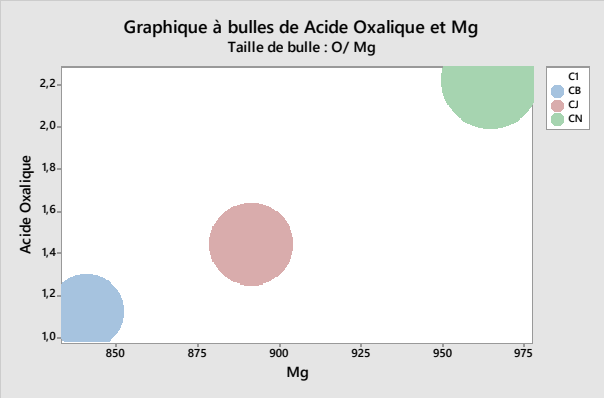


Figure 4 : Variation of molar ratio O/Mg

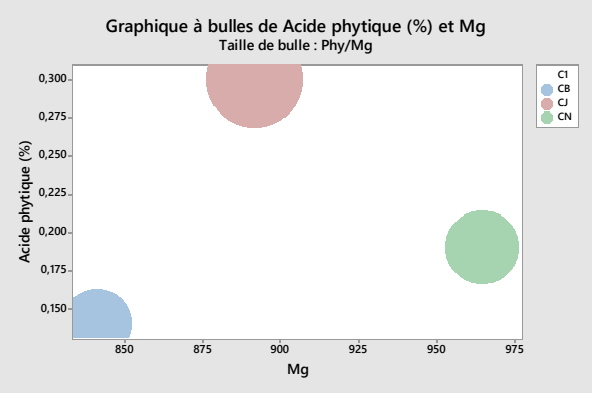


Figure 5 : Variation of molar ratio Phy/Mg

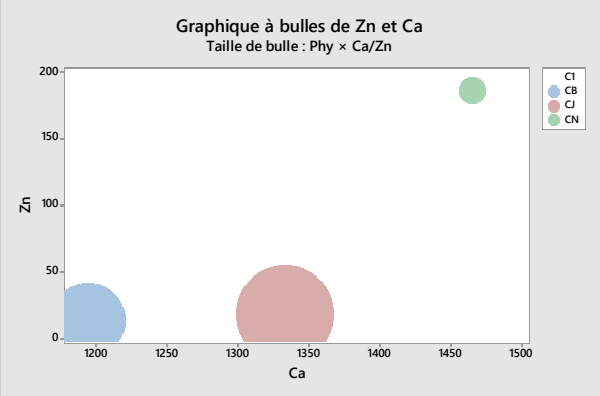


Figure 6 : Variation of molar ratio PhyxCa/P

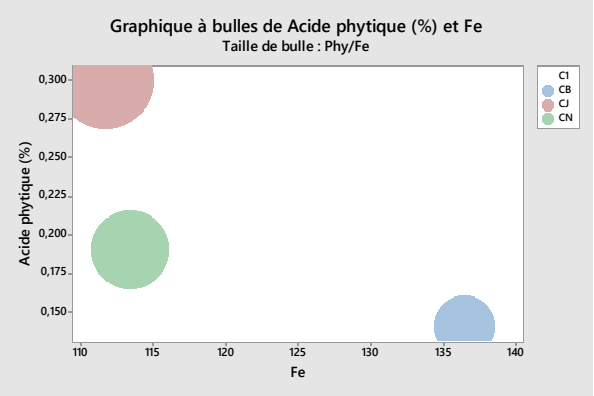


Figure 7 : Variation of molar ratio Phy/Fe

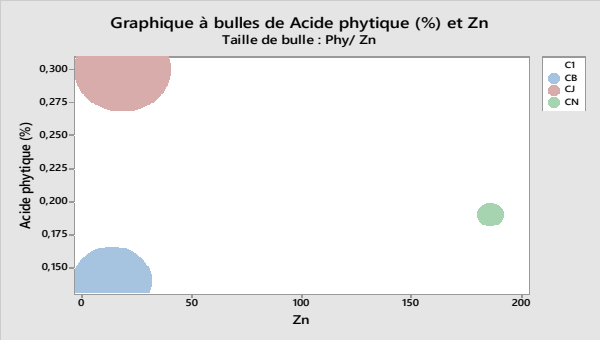


Figure 8 : Variation of molar ratio Phy/Zn

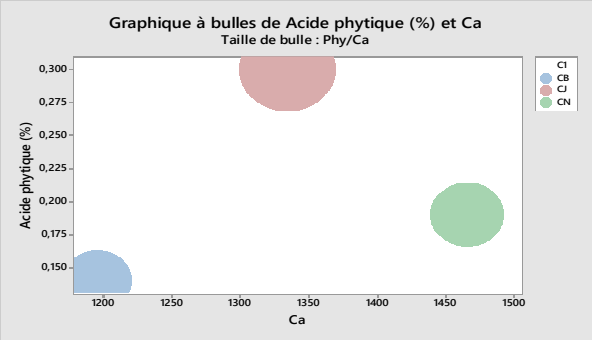


Figure 9 : Variation of molar ratio Phy/Ca

The highest Phy/Fe molar ratios; Phy/Zn; Phy/Mg; Phy/Ca; Phy/P; Phytate × Ca/Zn are obtained in the tubers of the yellow cultivar with 26.94 respectively; 169.68; 3.37; 2.25; 1.5; 22.62. This observation indicates that the proportion of phytate is higher than that of minerals and in turn limits the assimilation of minerals such as zinc, calcium, phosphorus, magnesium and iron. Furthermore, black nutsedge tubers contain the largest ratios for the rest of the molar ratios considered T/p; O/Ca; O/ Mg with respectively 0.12; 15.16 and 23.02. It appears that brown nutsedge tubers are those with the lowest quantities of anti-nutritional factors.

Mineralogical reports

The mineralogical ratios of the tubers of the three nutsedge cultivars (table 6) make it possible to assess the balance between Ca minerals; Mg and P provided.

Tableau 6: Mineralogical ratios

	Ca/P	Ca/Mg	Na/K
CB	0,629 [a]	1,420 [a]	0,339 [a]
CJ	0,667[b]	1,496 [a,b]	0,127[b]
CN	1,080[b]	1,51 [b]	0,153[b]

CB: Brown Tigernut; CJ: Yellow Tigernut; CN: Black Tiger Nut

Means not sharing any letters are significantly different.

The mineralogical ratios considered are Ca/P; Ca/Mg and Na/K. Considering the values obtained from the ratios, it should be noted that the tubers of yellow nutsedge cultivars have the highest Ca/P and Ca/Mg ratios with respective values of 0.667 and 1.496. It therefore appears that the highest Na/K is contained in the tubers of brown nutsedge cultivars.

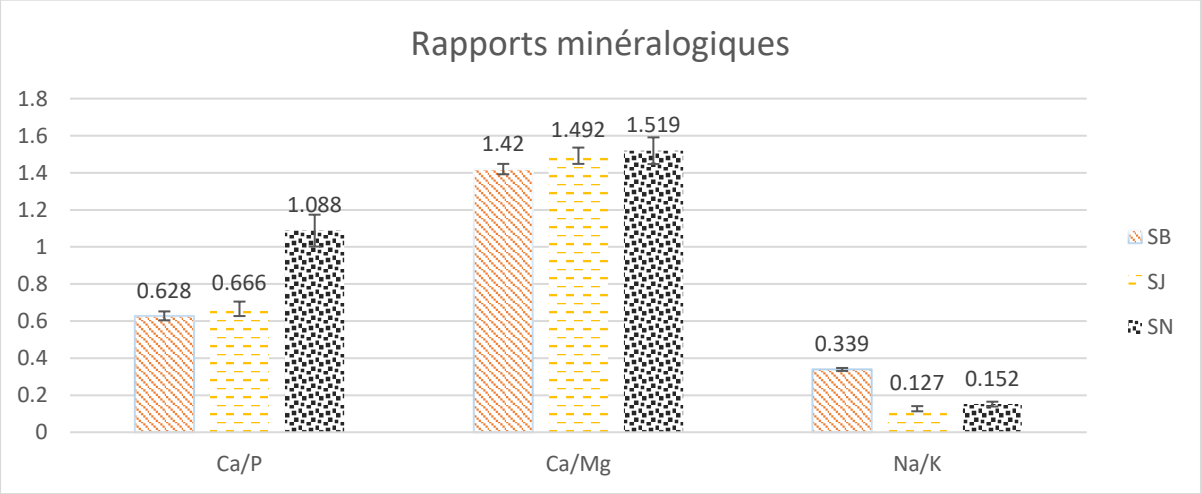


Figure 10: Mineralogical ratios

Heavy metal composition

Table 7: Heavy metal composition

Heavy metals measured such as copper (Cu), arsenic (As), cadmium (Cd), lead (Pb) and nickel (Ni) show different results (Table 7)

	Heavy metal contents (mg/kg)				
	Copper (Cu)	Arsenic (As)	Cadmium (Cd)	Lead (Pb)	Nickel (Ni)
CB	6,62 ± 0,02[a]	< 0,0007	0,19 ± 0,01[a]	< 0,0007	< 0,0007
CJ	4,13 ± 0,01[b]	< 0,0007	0,14 ± 0,02[a,b]	< 0,0007	< 0,0007
CN	4,03 ± 0,01[c]	< 0,0007	0,15 ± 0,01[b,c]	< 0,0007	< 0,0007

CB : Souchet Brun ; CJ : Souchet Jaune ; CN : Souchet Noir

Table 7 summarizes the heavy metal contamination rates according to the varieties of nutsedge tubers. After analyzing the results, it is found that heavy metals such as arsenic (As); lead (Pb) and nickel (Ni) are present in trace amounts in the different tubers taken into account in this study. Furthermore, metals such as copper (Cu) and cadmium (Cd) are minerals for which maximum tolerated intakes have been identified and presented as references. Thus the tubers of brown nutsedge; yellow and black have values of 6.62 ± 0.02a, respectively; 4.13 ± 0.01b and 4.03 ± 0.01c for copper (Cu) and 0.19 ± 0.01a; 0.14 ± 0.02a, b; 0.15 ± 0.01b, c for Cadmium (Cd). With regard to the copper values, it is noted that these values are statistically different from reference values (Infant) (Figure). For the metal cadmium, only black nutsedge tubers have a content statistically equal to the reference. It is therefore important to refer to the references summarizing the Maximum Tolerated Intake (AMT) for copper.

Summary of characters according to cultivars

Summary and distance between cultivars

Nutgrass cultivars have different characteristics. However, a distinction is present between it and presented through the dendrogram below (Figure 11).

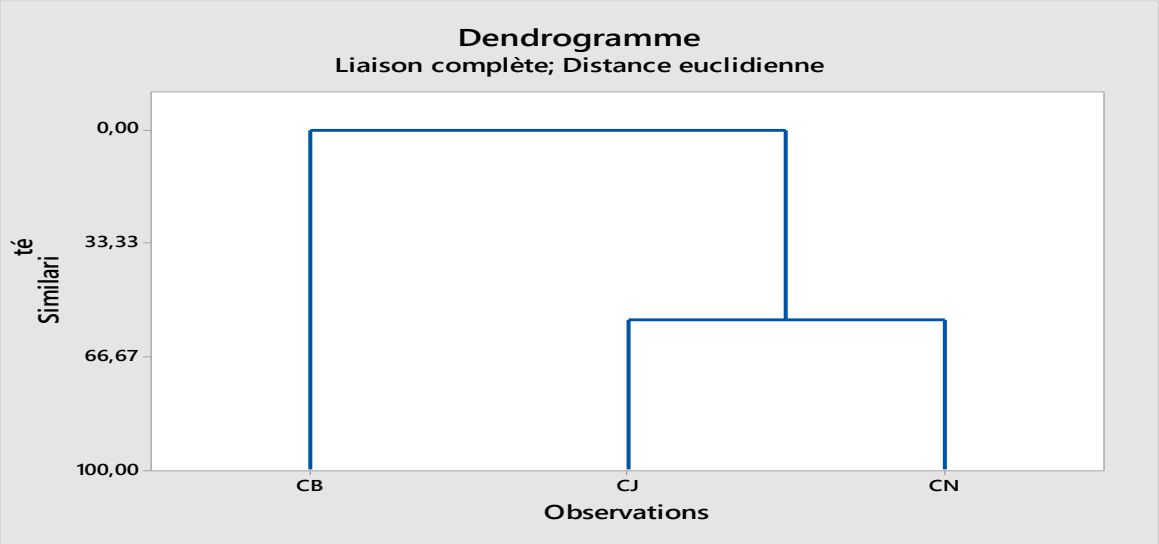


Figure 11 : Dendrogramme de liaisons entre les cultivars de souchet

Figure 11 shows a dendrogram that reports the Euclidean distance between cultivars as a function of similarity. From his reading, he reveals that the tubers of the yellow and black cultivars have fairly similar characteristics from the point of view of technological, nutritional and health assessments compared to those of the tubers of the brown cultivar.

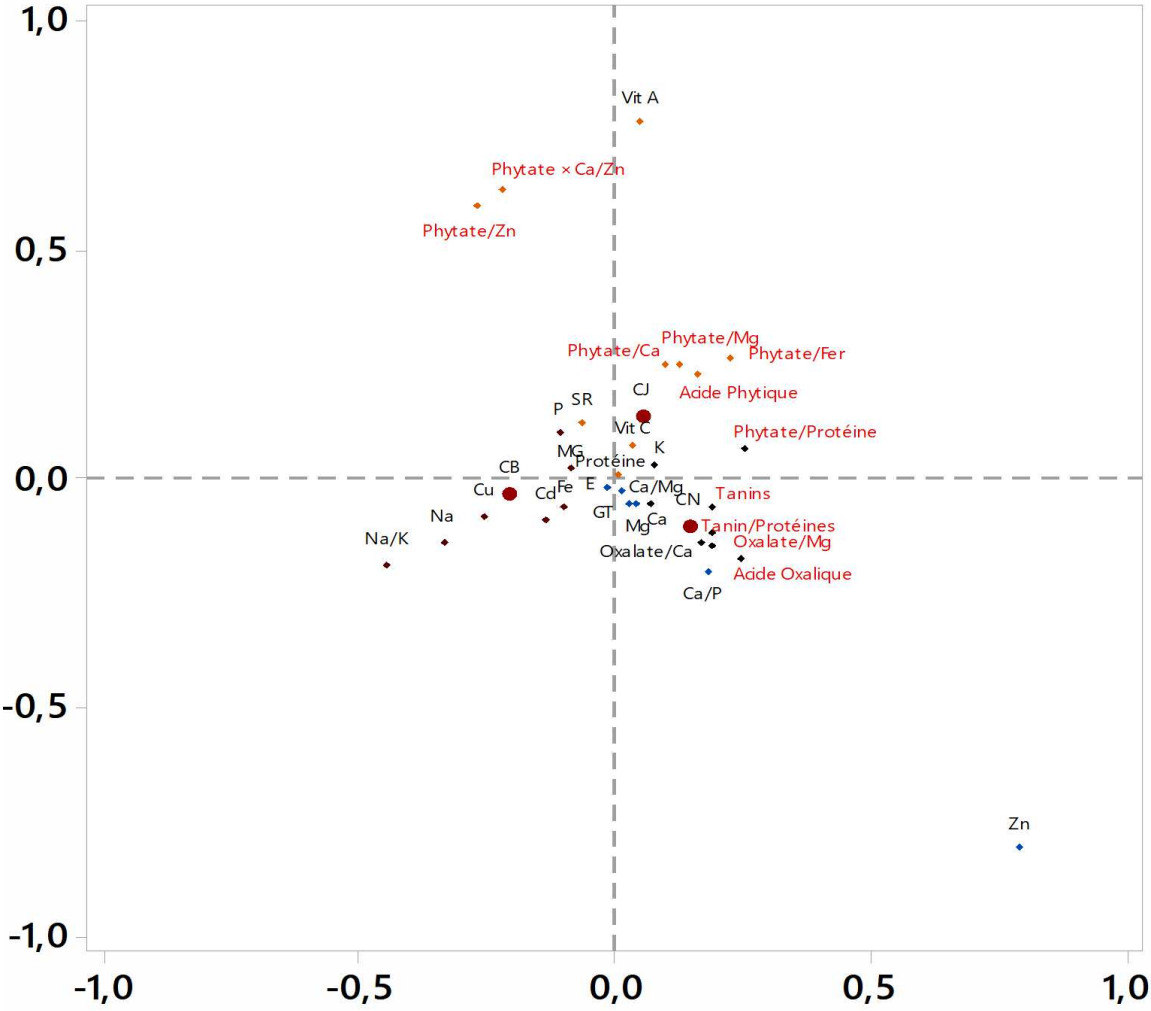


Figure 12 : Carte factorielle des caractéristiques des cultivars de souchet

Cultivars are linked to traits with the best correlations. The analysis takes into account not only nutritional values but also antinutritional factors as well as molar ratios. These two categories of nutritional constraints are red. Figure 11 shows the cultivars divided into two classes, yellow and black in one and brown in the other. The brown cultivar, although presenting the smallest tubers in volume and mass, is the one which gives characteristics which correlate more with fat (MG), sodium (Na), iron (Fe) and phosphor (P). although containing heavy metals, the consumption of tubers of this cultivar does not really represent a risk because these metals are found in very low composition below standards or even in trace amounts. The yellow and black cultivars, although having similar nutritional characteristics, they are also full of nutritional constraints to limit the bioavailability of said nutrients. It emerges from the analysis of this factor map (figure 12) that the cultivar with the best contents of macronutrients (proteins and fats), reducing sugars and Vitamin C brings together the yellow tubers. It also contains nutritional constraints, namely worrying molar ratios including phytate/Ca, phytate/MG, phytate/iron and the phytate factor despite its important morphological characteristics. The black cultivar, close to yellow in morphology, mostly contains nutritional constraints and correlates less with

nutrients. For this purpose, the black cultivar presents the best correlations with parameters such as tannins, tannin/proteins, Oxalates/Mg, Oxalates, Phytate/Proteins.

Discussion

Nutsedge is a weed plant whose tubers have a higher nutritional potential than commonly consumed tubers such as yams, sweet potatoes, etc. But the lack of knowledge of its characteristics leads to its non-valuation. In this context, the objective was to characterize the tubers of the three nutsedge cultivars taken into account in this study. The tubers of the three nutsedge cultivars hydrate or completely dehydrate over varying periods of time. Thus, the complete hydration time of cultivars of nutsedge tubers is all the more important as they have a high density. The same goes for the reverse process. The results obtained either by hydration or dehydration show that nutsedge seeds can be kept dry and hydrated by soaking without losing their crisp texture (Parker et al., 2000). Thus the incorporation of water does not affect the internal structure of the tubers. However, the values for average mass and density from Parker et al. (2000) differ from those obtained in this study. According to Parker (2000), the average mass of 0.257 g is greater than that of brown nutsedge cultivars but lower than those of yellow and black nutsedge cultivars. This difference is also noted in terms of density because all the values relating to the three cultivars are lower than those of (Parker et al., 2000) when he stated that the density of tiger nut is 1.186 g/ml. A common characteristic of dried nutsedge is its hard texture and low moisture content; therefore, soaking is essential to make them easily edible and to ensure acceptable sensory quality. The hydration capacity was established at 0.111 g/tuber and is directly linked to size; the larger the tuber, the greater the hydration capacity, that is to say the quantity of water absorbed at room temperature by the tuber (Coskuner et al., 2002). The value of hydration capacity can be indexed to the initial weight of the nutsedge by dividing the hydration capacity by the initial weight per tuber and is called hydration index (0.614 in nutsedge tubers). Additionally, hydration capacity is related to the permeability and water absorption of the shell and chemical composition, as is swelling capacity. Swelling capacity is an alternative test of hydration capacity and is a volumetric measurement based on the difference in volume between dry and soaked materials. The swelling capacity determined by Coskuner et al. (2002) in nutsedge was 0.100 mL/tuber. Certain chemical components, such as proteins, starch, lipids, and seed or tuber coat components, enhance or hinder the water absorption properties of plant materials. Tigernut is characterized by a good nutritional profile. The tubers of brown nutsedge cultivars are the most acidic (Ph=5.37) and have the lowest mass of 1000 grains and volume. On the other hand, the largest masses of 1000 grains and volume are held by the tubers of black nutsedge cultivars with respectively 1300.0±14.1 and 1kg/0.08862 ± 0.0008. These results are different from those obtained by other authors. In fact, the water content (10%) is much lower than that of Lorbardo et al. (2011) and Murniece et al. (2011) for Ipomoea batata (78.75%); from Abara (2011) for Discorea spp (62.5%); by Olayiwola et al. (2009) Lai et al. (2011) for Ipomoea botatas (70.54%) and Maieves et al. (2012) for Manihot esculentus (60.00%). According to Coskuner et al. (2002); Alegria-Toran et al.And Farré-Rovira (2003) tiger nut tubers have a water content of 26.00%; a lipid content of 24.49%; a protein content of 5.04; an ash content of 1.70; a reducing sugar content of 1.70 and a carbohydrate content of 43.30%. On the other hand, for nutrients such as lipids; proteins and carbohydrates the results obtained during this

study on nutsedge tubers are in much higher proportions than those of potatoes (0.16%; 1.97% and) (Lorbardo et al. (2011) and Murniece and al. (2011); than those of yam (0.20%; 2.55% and 34.60%) (Olayiwola et al.,2009); than those of Ipomoea botatas (3.88; 0.66 and 25.74) and those of Manihot esculentus (0.30%; 1.40% and 38%) (Maieves et al.,2012). As part of this study, the results obtained are similar to those of several authors when they affirmed that tiger nut has a protein content ranging from 3.98 to 9.70%, Oladele and Aina (2007) and a carbohydrate content varying between 22.08 and 75.88% Salau et al. (2012). The oil content is approximately 20.50 ± 0.3%. This value corroborates those of certain authors. Authors have reported that the oil content of yellow nutsedge varies between 22.8 and 32.8 g/100 g (Coskuner et al., 2002). However, the results obtained are different from those of some other authors depending on some parameters. Thus, the maximum content obtained (21.10 ± 0.3%) in our study is lower than those of Salau et al. (2012), 24.00 to 35.43%; Similarly, the lipid and protein constituents of tiger nuts are lower than those of nuts (Venkatachalam and Sathe 2006; Ros 2010; Ćarcel et al. 2011; Panahia and Khezri 2011). The macronutrient constituents being variable, the quantity of energy is also variable. Thus, brown nutsedge provides 452.14 ± 5.9 kcal. This quantity of energy is much lower than the values of other other authors. Oladele and Aina (2007) Salau et al. (2012) found energy values of 1511 kJ / 100g and 1754.98 kJ / 100g respectively. Asante et al. (2014), nutsedge tubers from Twifo-Praso in the central region of Ghana contained 17.66% fat, 5.66% protein, 1.23% ash, 64.16% carbohydrate, 11, 62% fiber and an energy value of 1867.07 kJ / 100 g. Likewise, the oil content is around 24.5%. Some authors have reported that the oil content of yellow nutsedge varies between 22.8 and 32.8 g/100 g (Coskuner et al., 2002). These differences can be justified by the variability of the areas where the nutsedge comes from, the inputs provided and also the types of soil considered during cultivation.

From the results obtained from the mineralogical analysis, it appears that the cultivars of nutsedge tubers are very rich. This wealth is shared and depends on the types of cultivars. Thus, not only are differences noted between cultivars but they can also arise in comparison with the results of other authors. Thus, the results obtained from the evaluations of mineral element contents are lower than those of Glew, (2006) when he affirmed at the end of his studies that nutsedge tubers have different mineralogical proportions in proximal composition (g/100 g) at namely: calcium: 18.80, sodium: 8.21, potassium: 557.30, magnesium: 76.30, phosphorus: 193.70, iron: 5.29, zinc: 1.12, copper: 0.24; Oladele & Aina, 2007: calcium: 140, sodium: 235, potassium: 255, magnesium: 56.30, phosphorus: 121, iron: 0.80, zinc: 01, copper: 0.01. The same observation is made in comparison with the results (g/100 g) of Asante et al. (2014): calcium: 1.68, sodium: 48.45, potassium: 805.20, magnesium: 64, phosphorus: 39.83, iron: 0.39, zinc: 3.84, copper: 0.35. The function of this calcium mineral is to increase the mechanical strength of the bone by solidifying the network of collagen fibers. Extracellular calcium plays a role in the integrity, stability and permeability of cell membranes, regulating neuromuscular excitability and cardiac function. Minerals are in varying proportions in foods. These foods intended for consumption must maintain the balance in the mineralogical relationships in the living organism and humans in particular. Ca/Mg ratios; Ca/P and Na/K differ from one nutgrass tuber to another. Considering the statistical results obtained in this work, it appears that the Ca/P and Na/K ratios, the yellow and black nutsedge tubers present

statistically identical ratios but different from that of the brown nutsedge tubers. The acquisition and maintenance of bone mass, as well as its strength, are influenced by environmental factors, including physical activity and nutrition. Consumption of nutsedge tubers is necessary because they contain minerals such as sodium and potassium in considerable proportions. The sodium contained in tiger nuts is essential for the conduction of nerve impulses and is an essential factor in hydro-electrolyte balance, through its role in the osmotic pressure of extracellular fluids, where it represents 95% of all cations. Potassium deficiency is observed during vomiting, diarrhea and excessive urinary loss due, for example, to taking laxatives or diuretics. The deficiency, which affects the neuromuscular system, can lead to paralysis and cardiac arrhythmia. The minimum requirements are estimated at 400 to 600 mg/day, again with strong possibilities for adaptation, except in the elderly. Thus, the consumption of tiger nut tubers largely covers the needs recommended by the WHO. After two-by-two comparisons with Tukey's method and a 95% confidence level, it is found that nutsedge tubers contain statistically non-different amounts for Mg minerals; Fe and Cu. Tigernut contains good proportions of essential minerals such as zinc, magnesium and potassium (Glew et al., 2006; Oladele and Aina, 2007; Asante et al., 2014). The total amount of Ca and P in a 70 kg adult organism is approximately 1300 and 700g, of which approximately 99% and 80% respectively are found in bone. The Ca/P molar ratio obtained during this work varies between 0.628 for brown nutsedge and 1.088 for black nutsedge. It is the same when this ration is compared to that of cow's, goat's and sheep's milk which is around approximately 1.3. (Guéguen et al., 2001). In relation to the phosphocalcic balance, an excess intake of phosphorus can in the long run, if the intake of calcium is insufficient (Ca/P < 1), cause secondary hyperparathyroidism and induce a loss of bone mass. It is therefore all the more important to ensure that the calcium intake is, given this level of dietary phosphorus, in a satisfactory ratio (Guéguen et al., 2001). According to (Guéguen et al., 2001, 99% of the body's calcium is found in the skeleton, of which it is the main constituent and ensures rigidity, in the form of crystallized hydroxyapatite and amorphous calcium phosphate fixed on collagen, in a Ca/P ratio close to 2. The value of 185 mg/Kg obtained in black nutsedge shows that if afterwards (Arnaud., 2001), zinc plays an essential role in all stages of protein synthesis, the activation of ribonucleic acid (RNA) and DNA polymerases, the synthesis of prostaglandins and has an antioxidant function through its structural position in superoxide dismutase, copper-zinc dependent, then black nutsedge could be used to produce nutraceuticals as a plant matrix while preserving this zinc potential. Considering these needs, it is therefore clear that nutsedge tubers can cover the daily requirements. Regarding the copper composition of the tubers, the values obtained are lower than those of Coudray et al. (2001). Some antinutritional parameters are evaluated on the tubers of the three nutsedge cultivars taken into account in this work. The overall antinutritional factors, oxalic acid, tannins and phytic acid are the parameters taken into account. The values obtained for these parameters are presented according to each cultivar (table 5). Looking at the information, significant variations emerge for the parameters global antinutritional factors and oxalates. Thus, we see a significant difference for the first from one cultivar to another with respectively 1.53 ± 0.17% (brown cultivar); 2.12 ± 0.07% (yellow cultivar) and 2.86 ± 0.12% (black cultivar). The black cultivar contains 2.22 ± 0.021 % of oxalic acid much higher than those held by the yellow and brown cultivars which for their part share statistically identical values. Regarding the two other remaining parameters, the values

obtained are statistically identical for each parameter and for a cultivar to another. The investigations of antinutritional factors made it possible to evaluate the contents of Oxalic Acid, Tannins and Phytic Acid. The proportions of tannin obtained for the three cultivars are much lower than those of Vijayakumari et al. (1996) when they estimated this proportion at 2.37%. This value is respectively 8 times, 6 times and 5 times higher than our values for brown, yellow and black cultivars. The tannin contents of the cultivars are also lower than those of other crops as reported by Fagbemi (2005) where they claimed 1.75% for guar gum seeds. However, they are higher than 0.15% and 0.07% for soybeans and brown millet (Odumodu., 1995). Despite the treatment reduction in the tannin content carried out by Oladélé et al. (2009), the tannin levels of our cultivars remain lower. In fact, the tannin values resulting from technological operations such as soaking varied between 0.93 and 2.02%. , denoting a reduction of 15 to 61%. Although all soaking processes reduced tannins, soaking at room temperature had the lowest reduction (15%) while tigernut soaked at 60°C for 7h had the highest reduction (61%). Increasing the temperature and soaking time also significantly reduced the tannin concentration (P = 0.05). This large difference between the values could be justified by the type of soil and previous crops, type of fertilizer etc. Although roasting has a significant impact in reducing tannin in Fagbemi's farms (2005), it is noted that the raw tuber contents of our cultivars remain lower than its values. Indeed, he estimated that roasting significantly reduced the tannin content of tigernut (P=0.05) up to 71%, which was higher than the value recorded for soaking. The tannin content of roasted tigernut varied between 0.7 and 1.51% with a reduction of 36-71%. The maximum phytate value recorded for the three raw nutsedge cultivars is less than 0.30% and is obtained for yellow nutsedge. This value is also very low and is more than 71 times the findings of 'Odumodu et al. (1992) while they estimated the phytate content of raw tiger nut at 21.42%. It is also lower compared to the 8.25 and 4.25% reported for white sesame and black millet respectively (Odumodu et al., 1992) and 0.18%. The oxalate dosages of our cultivars report sufficiently low values for 13.12%, 5.46-8.28% and 2.97-5, 67% for raw, soaked and grilled tigernut (Obasi etal.,2008).

Conclusion

Nutsedge is a weed plant whose nutritional benefits are considerable. Brown, yellow and black nutsedge cultivars have different nutritional compositions and technological properties. Yellow nutsedge tuber cultivars have the best energy compositions; protein; reducing sugars; ashes; vitamins C; HAS; K and P. Black nutsedge cultivars contain the best proportions of carbohydrates; magnesium; calcium; zinc while those of brown nutsedge combine in a high proportion the remaining parameters measured, namely fat; the iron ; sodium; the copper. So at the end of this work, it should be noted that yellow nutsedge tubers combine almost all of the advantages distributed in the other varieties. It therefore comes at the right time to be the subject of better valuation. Afin d'optimiser les usages des cultivars, les cultivars doivent subir des traitements technologiques visant à réduire voir éliminer les facteurs antinutritionnels pour amenuiser les rapport molaires et par ricochet améliorer la biodisponibilité des nutriments. In order to optimize the uses of cultivars, cultivars must undergo technological treatments aimed at reducing or even eliminating anti-nutritional factors to reduce molar ratios and, in turn, improve the bioavailability of nutrients.

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