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Phytochemical and nutritional composition of *Cyperus esculentus* L. (Cyperaceae) whole tubers and Defatted Flour

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ABSTRACT

This study was carried out on dry tubers of *Cyperus esculentus* (Cyperaceae), collected in three northern localities of Côte d'Ivoire, with the aim of determining the mineral, phenolic and nutritional compositions of whole tubers and its defatted flour. The mineral composition was determined using a scanning electron microscope (SEM) and the quantitative determination of the phytoconstituents was carried out by spectrophotometry. The nutritional and antinutritional parameters were determined by spectrophotometric and titration methods. As a result of the study, it was found that *Cyperus esculentus* tubers contain many macro- and trace elements with high levels of potassium (626.64-999.74 mg/100 g), phosphorus (494.35-544.60 mg/100g) and magnesium (124.25-146, 07mg/100g). The contents of whole tubers and those defatted in fat, protein, total carbohydrates and energy values were significant. As for the contents of total phenols and flavonoids, hydrolysable and condensed tannins, they vary respectively between 4215.52 and 5106.32 / 3740.52 and 4570.00 µg EAG/g DM; 10.80 and 14.68 / 6.00 and 8.10 µg EAG/g DM; 0.165 and 4.555 / 0.23 and 0.35 µg EAG/g DM; 725.33 and 1486.25 / 242.50 and 1110.98 µg EC/g DM. The analysis of the antinutritional (fibres, oxalates et phytates) parameters was carried out only on the defatted flour, whose contents are respectively 9.32 – 9.81%; 0.0495 – 0.055mg /100g; 12.24 – 33.23 mg/100g. With regard to the nutritional and energy values determined, the tubers of *Cyperus esculentus* have significant nutritional potential. In addition, its defatted flour contains natural proteins and sugars, which makes it suitable for animal feed.

Keywords: Cyperus esculentus, whole and defatted tubers, chemical composition, Côte d'Ivoire

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INTRODUCTION

The cultivation and consumption of all foodstuffs, including the fruits of tuberous plants, can contribute to the solution of an urgent problem of nutrition linked to an increase in population. One of the healthy and tasty tubers is nutsedge, *Cyperus esculentus* , which unfortunately is not in great demand today by the Ivorian population. *Cyperus esculentus* is a perennial herbaceous plant species in the family Cyperaceae, cultivated as a food plant due to its edible tubers (also called nuts). It is grown in Spain, in North and West African countries (Nigeria, Cameroon, Senegal, Ghana, Côte d'Ivoire) and also in South America and Chile. *C. esculentus* is known by several names: tiger nut, tiger nut, chufa, ground almond or ground almond. For several years, the tubers of *C. esculentus* have been used as a preventive or therapeutic agent in production areas[1]. Its applications in traditional medicine are numerous[2-4]. Tubers are used as healthy food for humans and animals due to its nutritional and functional properties[3,5]. Despite all its nutritional and medicinal benefits, tiger nut is not used enough. Current research on *C. esculentus tubers* is mainly focused on the organoleptic, nutritional and phytochemical properties of the whole fruit and especially on the chemical composition of its fat. However, there is almost no information on the chemical and nutritional composition of the residue obtained after oil extraction from the tubers, although its use in animal feed may be beneficial. Therefore, we were interested in studying the chemical composition of whole tubers of *Cyperus esculentus* and its defatted flour.

MATERIALS AND METHOD

Plant material

The plant material is made of *Cyperus esculentus* yellow tubers harvested in April 2020 in three northern departments of Côte d'Ivoire: Korhogo (Lélékaha village, 9° 27' 41" North 5° 38' 19" West), Sinematiali (Klolekaha village, 9° 35' North, 5° 23 ' West) and Dabakala (Sokala-Sobara village, 8° 21' North, 4° 31' West). Authentication species was carried out at the National Floristic Center (CNF) of Félix Houphouët-Boigny University (herbarium N°UCJ004623). Tubers from Klolekaha, Lélékaha and Sokala-Sobara are respectively named TKS, TLK and TSD (Figure 1). They are cleaned under running water, dried at 50°C in an oven for 24 hours, ground and stored in hermetically sealed glass jars.

TKS

TLK

TSD

Tubers from Klolekaha (TKS), Lélékaha (TLK) and Sokala-Sobara (TSD)

Figure 1: *Cyperus esculentus* tubers

Analysis of mineral composition

A quantity of ash, obtained from the whole powder (TKS, TLK and TSD) is placed under an X-ray beam from a Scanning Electron Microscope (SEM, FEG Supra 40 VP Zeiss), equipped with an X-ray detector X (Oxford Instruments) connected to an EDS (Inca Dry Cool) microanalyzer, without liquid Nitrogen. The sample atoms are excited and then tend to return to the ground state in releasing energy, in the form of X photons, whose spectrum is characteristic of the chemical composition of the sample. Spectrum analysis made it possible to determine the mass concentrations of pure elements.

Extraction fat and obtaining the residue

15 g of tuber powder (TKS, TLK and TSD) were mixed carefully with 6 g of $MgSO_4$. The mixture was introduced into a Soxhlet flask containing 130 ml of n-hexane and refluxed during 2 h in a heating cap[6]. The fat (MG) was dried and weighed after distilling the n-hexane using a rotary evaporator. The residues (RKS, RLK and RSD) obtained after extraction of MG, are dried in an oven (50°C) for 2 h and kept to determine their mineral and nutritional compositions.

QUANTIFICATION OF PHYTOPHENOLS

Extraction of phenolic compounds

5 g of the whole powder (TKS, TLK and TSD) and residues (RKS, RLK and RSD) were macerated in 60 ml of MeOH (80%). This operation was repeated twice. The respective macerates are combined, reduced using a rotary evaporator and dried in an oven (50°C). The hydromethanolic extracts (TKS, TLK and TSD) and residues (RKS, RLK and RSD) were obtained for the determination of their phenolic composition.

Total polyphenols (TP)

0.05 g of extract (TKS, TLK, TSD, RKS, RLK and RSD) are dissolved in 10 ml of distilled water. To 1 ml of this mixture diluted to one tenth are added 1.5 ml of Na_2CO_3 (17%, m/v) and 0.5 ml of Folin-Ciocalteu reagent (0.5N). This mixture is incubated at 37°C for 30 minutes. Absorbance is read at 760 nm against a blank. This quantification is carried out according to the gallic acid calibration (0 to 1000 µg /ml) prepared under the same conditions as the extracts. The results are expressed in equivalent microgram of gallic acid per gram of dry matter (µg EAG/g DM)[7, 8].

Totals Flavonoids (FT)

0.05 g of extract (TKS, TLK, TSD, RKS, RLK and RSD) are dissolved in 10 ml of distilled water. To 2 ml of this mixture are added 100 µl of Neu's reagent. The absorption is determined at 404 nm

and compared with that of quercetol (0.05 mg/ml). The percentage of TF is calculated as quercetol equivalent according to the formula[9].

$$\mathbf{F}(\%) = \frac{\mathbf{0,05}\ \frac{\mathbf{Aext}}{\mathbf{Aq}}}{\mathbf{Cext}} \times \mathbf{100}$$

Aext: extract absorbance; **Aq:** quercetol absorbance; **Cext:** extract concentration (mg/ml)

Hydrolysable tannins (TH)

0.05 g of extract (TKS, TLK, TSD, RKS, RLK and RSD) are taken up in 10 ml of 80% ethanol. To 1 ml of this solution are added 3.5 ml of a solution of $FeCl_3$ (0.01 M in 0.001 M HCl). The absorbance is read with a UV spectrophotometer at 660 nm[10]. The TH content was expressed according to the expression:

$$\mathbf{TH}\ (\%) = \frac{\mathbf{Abs} \times \mathbf{M} \times \mathbf{V}}{\mathbf{E\ mole} \times \mathbf{m}}$$

Abs: absorbance; **E mole:** 2169 of gallic acid (constant in mole); **M:** mass = 300 g/mol; **V:** volume of the extract used; **m:** mass of the sample.

Condensed tannins (TC)

0.05 g of extract (TKS, TLK, TSD, RKS, RLK and RSD) are diluted in 10 ml of distilled water. To 400 µl of sample are added 3 ml of vanillin solution (4% in MeOH) and 1.5 ml of concentrated HCl. The mixture is incubated for 15 min and the absorbance is read at 500 nm. The TC contents are deduced from the catechin calibration (0-300 µg /ml), and expressed in micrograms of catechin equivalent per gram of extract (µg EC/g)[11, 12].

DETERMINATION OF NUTRITIONAL PARAMETERS

Quantification of sugars

Preparation of carbohydrate extract

2 g of powder (TKS, TLK, TSD, RKS, RLK and RSD) were macerated in 10 ml of 80% ethanol with stirring for 15 min at room temperature. The whole was centrifuged at 3000 revolutions/min for 5 min three times. The supernatants were collected, combined and 2 ml of the lead acetate solution (10%) was added. The mixture again was centrifuged at 2000 rpm for 10 min. The supernatant was again collected and 2 ml of oxalic acid solution (10%) was added. The whole was centrifuged at 2000 rpm for 5 min. The recovered supernatant was reduced until a viscous solution was obtained, which was supplemented to 25 ml with distilled water[13, 14].

Total sugars (ST)

To 150 µl of carbohydrate extract, 1 ml of phenol (5%) and 5 ml of H_2SO_4 (97%) were added. The mixture was homogenized, cooled and then its absorbance is read on a spectrophotometer at 490

nm against a control. The contents were determined from the glucose calibration line (from 0.067 to 1 mg/ml) prepared under the same conditions as the extract[15, 16].

Reducing sugars (SR)

To 150 µl of carbohydrate extract was added 300 µl of 3,5-dinitrosalycilic acid (DNS). The mixture was incubated for 5 min in a boiling water bath, then to the cooled mixture 2 ml of distilled water are added. The absorbance of the mixture is read at 540 nm and the SR contents were determined from the glucose calibration line (0.067 to 1 mg/ml)[17, 18].

Proteins (P)

Proteins were quantified using the Kjeldahl method[19, 14]. In a mineralizer, 25 ml of H_2SO_4 (96%) are added to 0.2 g of powder. The mixture was boiled (1 hour), cooled and placed in an auto-distiller. We added 20 ml of NaOH (0.5N) and 10 ml of H_2O to mineralisate. The distilled mixture is placed in an Erlenmeyer flask containing 20 ml of NaOH (0.5N). This mixture is titrated with a solution of HCl (1N) in the presence of phenolphthalein. The total nitrogen (N) content was determined according to the equation:

$$\mathbf{N} = \frac{(\mathbf{VHCl\ (b)} - \mathbf{VHCl\ (e)}) \times \mathbf{NHCl} \times \mathbf{14,01}}{\mathbf{10} \times \boldsymbol{V\ sample}}$$

$\mathbf{V_{HCl}\ (e)}$: volume of HCl required for the titration of the sample (ml); $\mathbf{V_{HCl}\ (b)}$: volume of HCl required for titration of the blank (ml); **NHCl** : titer of the HCl solution ; $\mathbf{V_e}$: volume of the test sample (ml); 14.01: atomic mass of nitrogen.

The protein content s (**T**) is obtained according to the expression: **T = Content N × 6.25**

Total Carbohydrates (GT) and Energy Value (EV)

The total carbohydrate contents and energy values of whole tubers (TKS, TLK, TSD) and defatted residues (RKS, RLK and RSD) were determined according to the methods described in the literature[20] following the following phrases:

$$\mathbf{GT}(\%) = \mathbf{100} - [\mathbf{Ashes}\ (\%) + \mathbf{Protéins}\ (\%) + \mathbf{Lipids}\ (\%) + \mathbf{Humidity}\ (\%)]$$

$$\mathbf{VE(Kcal/100g)} = [(\%\ \mathbf{Carbohydrates} \times \mathbf{4}) + (\%\ \mathbf{Protéins} \times \mathbf{4}) + (\%\ \mathbf{Lipids} \times \mathbf{9})]$$

DETERMINATION OF ANTINUTRITIONAL PARAMETERS OF DEFATTED FLOUR

Fibers

2 g of the dry residue (DKS, DLK and DSD) was boiled at reflux in 50 ml of sulfuric acid (0.25 N) for 30 min. After filtration and washing with 50 mL of H_2O, the residue was dried and boiled again in 50 mL of NaOH (0.31 N) for 30 min. The extract obtained was filtered and the rest was washed several times with hot water until the alkalis were completely eliminated. The residue, dried for 8 hours in an oven (105°C) then in a desiccator, was weighed (M_1) and then incinerated in an oven at

550°C for 3 hours. The ash was weighed (M_2) and crude fiber content (%)[21] was calculated according to the following expression:

$$\textbf{Fibers contents}\ (\%) = \frac{(\mathbf{M_1} - \mathbf{M_2}) \times \mathbf{100}}{\mathbf{M_e}}$$

M_1: mass (g) of the dry residue; **M_2**: mass (g) of ash obtained; **Me:** mass (g) of the sample.

Phytates

To 1 g of the defatted residue (RKS, RLK and RSD), 20 ml of HCl (0.65 N) was added. The whole was stirred for 2 h and then centrifuged at 3000 rpm for 10 min. To 0.5 ml of supernatant, 3 ml of Rose de Wade's reagent (0.03% [$FeCl_3$, $6H_2O$]; 0.3% sulfosalycilic acid) were added. The reaction mixture was kept in the dark for 20 min. Absorbance was read at 490 nm on a spectrophotometer against a blank. A calibration curve produced with phytic acid (0 to 10 mg/ml) made it possible to determine the phytate content in mg equivalent of phytic acid (EAP)/100g of dry matter (DM)[22, 23].

Oxalates

The oxalate contents were determined according to the methods described in the literature[24, 25]. To 2 g of defatted flour, 75 ml of H_2SO_4 (3M) were added. The whole was stirred for 1 hour at room temperature and filtered. 25 ml of filtrate were titrated with a $KMnO_4$ solution (0.05 M) until the violet solution turned pink. The oxalate content expressed in mg/100g of dry matter was calculated according to the following equation:

$$\textbf{Oxalates contents}\ (\mathbf{mg/100g}) = \frac{(\mathbf{2,2} \times \boldsymbol{Veq} \times \mathbf{100})}{\mathbf{m_e}}$$

Veq : volume of $KMnO_4$ used for the titration (ml); **m_e :** mass of the sample (g).

RESULTS AND DISCUSSION

Mineral composition

The results show that *C. esculentus* tubers of contain many essential macro elements and trace elements for the human organism (Table 1). It is noted that the fruits are rich in important elements, especially in K (626.64-999.74 mg/100 g), P (494.35-544.60 mg/100g) and Mg (124.25-146.07 mg/100g). Potassium is one of the most important components of intracellular fluid, it plays a main role in acid-base balance, muscle activity and in the synthesis of proteins and glycogen. As for phosphorus, it participates in bone formation and energy transformation as a main element of organic compounds and buffer solutions. Magnesium is a coenzyme in the metabolism of carbohydrates and proteins, it is also an integral part of the intracellular fluid. It is also involved in bone formation, tooth formation and in neuromuscular conduction[26]. In the literature, it has already been reported that the tubers of *C. esculentus* are a good source of K, P and Mg[27]. The

results show that the recorded K contents are similar to those of tubers harvested in Ghana (675.00 - 1424.1 mg/100 g)[28], Senegal (896.3 mg/100 g)[29] and in Burkina Faso (608.3-845.8 mg/100g)[30]. It can be seen that their Mg and P contents are considerably higher than those of Ghana (Mg: 53.5-74.7 mg/100 g and P: 27.9 -47.8 mg/100 g)[28] and Nigeria (Mg: 1.46 mg/100 g and P: 135.08 mg/100 g)[31] and comparable to those of Senegal (Mg: 104.9 mg/100 g and P: 267.8 mg /100 g)[29] and from Burkina Faso (P: 229.6-283.7 mg/100g and Mg: 107.3 mg/100g)[30]. With regard to Ca and Na, their contents are respectively 19.16 - 27.66 and 6.89-8.54 mg/100g, which are lower compared to those of tiger nuts from Nigeria (Ca: 130.42, Na: 34.3 mg/100g)[31, 32], from Ghana (Na: 48.45-107.58 mg/100g)[28], and comparable to those of Senegal (Ca: 26.07 ; Na: 15.80 mg/100g)[29] and Burkina Faso (Ca: 19.09-32.27 mg/100g)[30]. The trace element contents are also appreciable. Indeed, that of iron is higher compared to that of the species from Senegal (2.51 mg/100g)[29], and similar to the values of Nigeria and Burkina-Faso (16.00 and 11.44 mg/100g respectively)[30, 31]. Regarding aluminum, its presence was detected only in tubers from Burkina Faso, the content of which is comparable to our data (34, 35-39.86 mg/100g)[30]. These differences between the reported levels and ours could be explained by interactions of the plant with the environment, which can affect its mineral composition[33].

Table 1: Mineral composition of *Cyperus esculentus tubers* in mg/100g

	Na	Mg	Si	P	S	K	Ca
TKS	8.54±0.43	124.25±4.53	145.67±7.04	544.60±7.18	154.42±7.72	999.74±6.21	21.42±1.07
TLK	7.97±0.40	132.79±6.64	118.12±4.58	521.59±13.41	172.12±8.61	906.30±5.73	19.16±0.96
TSD	6.89±0.34	146.07±2,37	95.96±3,19	494,35±4,12	60.09±2.55	656,64±2,93	27,66±1,38
	Al	**Fe**	**Mn**	**Ni**	**Zn**	**Cu**	
TKS	28.77±0.36	13,65±0.68	3.92±0.20	-	6,86±0.34	1,26±0.06	
Tlk	45,49±2,27	18,62±0.93	3.15±0.16	5,16±0.26	5,16±0.26	-	
TSD	10.59±0.53	10.79±0.54	-	-	-	-	

Extraction yields

After extraction of fat (MG) from the tubers, whose yields vary between 23.64 and 27.66% **(Figure 1)**, residues DKS (75.15%), DLK (73.81%) are obtained. and DSD (70.53%). Moreover, extraction in 80% MeOH gave total extracts with similar percentages from whole tubers TKS (22.26%), TLK (24.37%) and TSD (25.70%) and from its defatted flours DKS (23.64%), DLK (24.72%) and DSD (27.66%). It appears that the presence of MG hardly influences the hydromethanolic extraction.

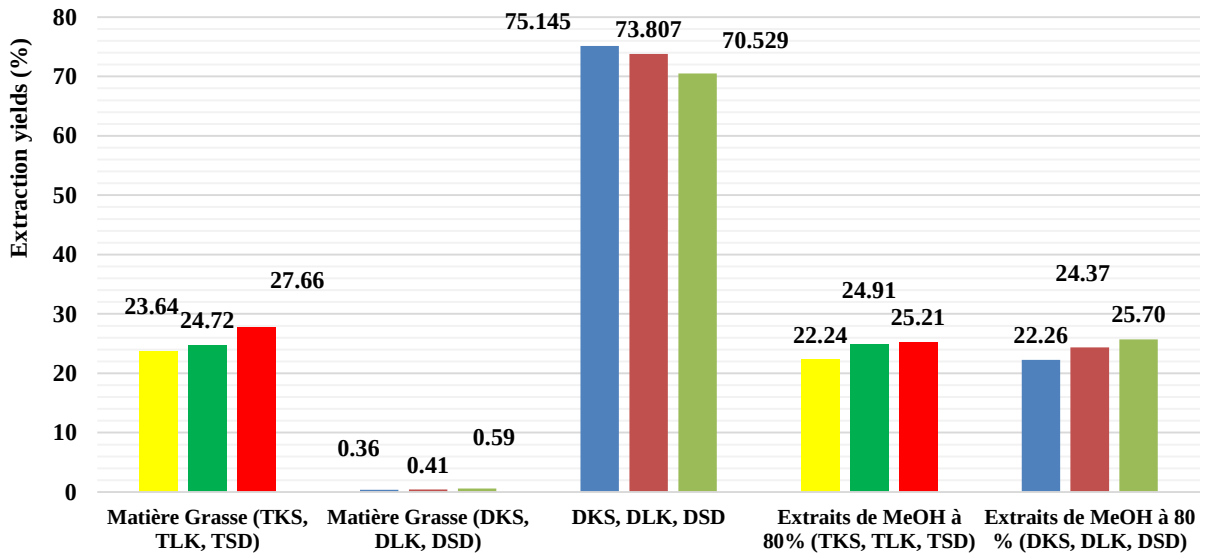

Figure 1: Simples extraction yields

Contents of phenolic compounds (PC)

The results of the various spectrophotometric assays carried out on the extracts of whole tubers (TKS, TLK and TSD) and its defatted flours (DKS, DLK and DSD) show that the levels obtained in phenolic compounds are variable. **(Table 2)**. It should be noted that the contents of total polyphenols (PT), total flavonoids (FT), hydrolysable tannins (TH) and condensed tannins (TC) are higher in whole tubers than in defatted ones. Indeed, the highest levels of PT (5106.32 µg EAG/g DM) and TC (1486.25 EC/g DM) are at TLK. All the same, the TH contents in DSD (0.272 µg EAG/g DM) and TC in DKS (1110.98 µg EC/g DM) are higher than in TSD (0.165 µg EAG/g DM) and TKS (725.33 µg EC/g DM).

Table 2: Phytophenol contents of whole (TKS, TLK, TSD) and defatted (DKS, DLK, DSD) of *C. esculentus* tubers

	TP (µg EAG/g DM)	TF (µgAG / gMS)	TH (µg EAG/g DM)	TC (µg EC/g MS)
TKS	4510.06 ± 50.29	10.796 ± 0.005	4.555 ± 0.005	725.33±058
DKS	3740.52 ± 14.92	8.104 ± 0.002	0.233 ± 0.006	1110.98±19.82
TLK	5106.32 ± 14.37	14.680 ± 0.002	1.095 ± 0.001	1486.25±9.58
DLK	4570 ± 6.39	5.997 ± 0.004	0.348 ± 0.002	926.67±21.21
TSD	4215.52 ± 86.21	14.588 ± 0.015	0.165 ± 0.004	958.33±8.33
DSD	4061.30 ± 11.63	7.929 ± 0.001	0.272 ± 0.002	242.50±10.61

TP: total phenols; TF: total flavonoids; TH: hydrolysable tannins; TC: condensed tannins

This analysis reveals that the contents of TH and FT in all the samples are low, on the other hand those of TC present considerable values, which indicates that the phenolic compounds of the nutsedge are preferentially TC. However, we note that the tiger nut tubers grown in Côte d'Ivoire give higher proportions of PT and TC than those of Nigeria whose contents are 17.40 µg EAG/g

DM and 56.1 µg EC/g DM, on the other hand the results of FT are clearly lower (14.68 µg EAG/g DM against 606.3 µg EAG/g DM)[34]. Also, the values obtained from PT in our study are greater than those (1800 µg EAG/g DM) tiger nut from Spain[35].

A significant difference is observable in the values of the PT content between our results and those of rapeseed whose seeds are well suited for the residue production. Indeed, the PT contents of whole rapeseed seeds are higher (16300 µg EAS/g DM) than ours and it should be noted that this value remains similar to that (16300 µg EAS/g DM) of its defatted flour[36]. This preservation of the PT residues present a practical interest for feeding cattle being substances with vitamin P activity. Also, the TC values obtained are in conformity with that determined in the rapeseed residue (1400 µg EC/g DM)[37].

Contents of nutritional parameters

The results we obtained on the parameters of *C. esculentus* whole tubers and defatted flour show that the contents found in proteins (P) and total carbohydrates (GT) are greater in those delipidated than whole **(Table 3)**. Indeed, the presence of P (up to 30%) and GT (up to 25%) increased after oil extraction, indicating that despite a very low fat content, the energy value of the defatted tubers remains high (360 kcal/100 g). This value is comparable with those of calorific products such as rice (357 kcal/100 g)[38], dry millet (360 kcal/100g) and quinoa (368 kcal/100g)[39]. The energy value of the tigernut is due to the high concentration of the GT (77.30-84.30%) because it generally comes from the lipid and carbohydrate intakes[40].

Table 3: Chemical composition of whole (TKS, TLK, TSD) and delipidated (DKS, DLK, DSD) tubers of *C. esculentus*

Settings	Samples					
	TKS	**TLK**	**TSD**	**DKS**	**DLK**	**DSD**
Humidity (%)	7.29±0.04	4.76±0.01	5.17±0.07	7.33±0.18	7.60±0.32	7.37±0.15
Ash (%)	2.10±0.01	2.01±0.07	1.52±0.03	3.11±0.07	2.89±0.06	2.29±0.07
Total sugars ST (g/100g)	14.14±0.01	21.25±0.02	20.92±0.59	13.80±0.59	18.88± 0.59	16.17 ± 1.02
Reducing sugars SR(g/100g)	9.31±0.57	9.65±0.58	7.98±0.03	7.32±0.58	5.32± 0.58	8.32 ± 0.58
Protein (%)	8.45 ±0.02	9.56 ±0.03	4.60 ±0.01	11.9 ±0.17	11.24 ±0.11	5.45 ±0.08
GT carbohydrates (%)	58.52	58.96	61.05	77.30	77.86	84.30
MG fat (%)	23.64 ±0.25	24.72±0.05	27.66±0.17	0.36±0.005	0.41±0.007	0.59±0.012
Energy value(Kcal/100g)	480.62±1.06	496.51±0.22	511.34±0.98	360.04±1.0	360.09±1.48	364.30±0.48
Fiber (%)	-	-	-	9,32 ±0,21	9,54±0,81	9,81±0,22
Oxalates (mg/100g)	-	-	-	0,055±0,08	0,050±0,05	0,055±0,08
Phytates (mg/100g)	-	-	-	33,23±0,51	19,47±0,16	12,24±0,81

The comparison of the results obtained with those reported by other authors shows some difference (Table 4). The quantities obtained in Table 3 are higher than those of the tubers harvested in Ghana, Nigeria, Egypt, Burkina Faso, Cameroon and Senegal, except those from Spain (8.9%).

Table 4: Chemical composition of *C. esculentus* tubers from other countries

	Spain, (*Bosch et al., 2020)*	**Ghana, *(Asante et al., 2014)***	**Nigeria, (*Oladele and Aina, 2007)***	**Egypt, (*Sabah et al., 2019)***	**Burkina Faso, (*Bado et al., 2015)***	**Cameroon, (*Hamadou et al., 2020)***	***Senegal (Ndiaye, 2021)***
Humidity,%	8.5	≤ 10	3.50	8.5	4.56-5.19	7.38	9.23
Ash,%	1.9	1.0-1.94	3.97	2.23	1.69-2.21	2.73	2.42
GM, %	31.4	12.87-29.54	32.13	30.01	24.9128.94	25.56	24.62
P, %	8.9	3.39	7.15	5.08	3.3-4.33	7.62	5.01
GT, %	43.2	50.69-73.47	46.99	45.73	64.7369.21	49.92	63.83
Fiber, %	9.0	7.42-13.54	6.26	14.8	-	15.56	32.80
VE Kcal/100g	-	424.19-501.62	-	-	-	445	500.04

Fat levels found are comparable to those of Burkina Faso, Cameroon, Senegal and certain varieties from Ghana, but they are lower than those of Spain, Nigeria and Egypt. Moreover, tubers from Côte d'Ivoire have more GT than those from other countries except Burkina and Senegal. In fact, tigernut from Spain, Nigeria, In fact, tigernut from Spain, Nigeria, Egypt and Cameroon contains 35% less than that from Côte d'Ivoire (Table 4). This analysis reveals that *C. esculentus tubers* from Côte d'Ivoire could meet daily macronutrient requirements (proteins and carbohydrates).

In the absence of data on the nutrient composition of *C. esculentus* residue, we compared it with that of rapeseed and sunflower, whose residue are mainly used in animal feed, with that of two oilseeds from the forests of Central Africa (*Ricinodendron heudelotii* and *Tetracarpidium conophorum*). It is noted that the tigernuts residue have relatively low protein contents (5.45 - 11.24%) compared to rapeseed (37.7%), sunflower (31.8%)[41], *Ricinodendron heudelotii* (44.57%) and *Tetracarpidium conophorum* (47.98%)[42]. On the other hand, defatted tigernut flours gave GT values (77.30-84.30%), which are approximately twice as high as those of rapeseed (40.0%) and sunflower (42.6%)[40]. It emerges that tigernuts residue could constitute a significant carbohydrate source in animal feed.

Levels of antinutritional parameters

The antinutritional factor of defatted tigernut flours is the presence of fibers and phytates (Table 3). Indeed, the abundance of fibers in meal decreases their energy values and their digestibility[43]. As for phytates, they trap minerals from food and lead to a decrease in their bioavailability. Also, they form complexes with proteins and modify them by deteriorating their functionalities[44, 45]. Phytates contents in tigernuts residue vary from 0.012 to 0.033%, with the highest content at TKS. However, this content is considerably lower than that found in the cakes of tiger nuts grown in Spain (8.9%)[35]. It should be noted that the fiber contents are almost equal in the three samples of defatted flour (Table 3) and are comparable with the contents found in the residue of *Ricinodendron heudelotii* (10.98%) *and Tetracarpidium conophorum* (9.76%)[42]. The fiber and

phytate contents in the defatted flour present an acceptable quantity to be used in the production of meal.

CONCLUSION

This study revealed that the *Cyperus esculentus* tubers contain minerals such as potassium, phosphorus, magnesium and iron. Nuts and defatted flour are also rich in phenolic compounds, particularly condensed tannins. The results of the nutritional analysis of defatted flour reveal that it's rich in carbohydrates, proteins in significant quantity, and has a significant caloric intake. Based on the results of the study, we can say that *Cyperus esculentus* tubers, by its high nutritional and biological values, present concentrated sources of nutrients. As for defatted flour, it can be used as a promising raw material in the food industry.

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