International Journal of Biochemistry Research & Review
13(2): 1-9, 2016, Article no.IJBCRR.28217
ISSN: 2231-086X, NLM ID: 101654445

SCIENCEDOMAIN *international*
www.sciencedomain.org

Physico-chemical and Nutritive Properties of Seeds and Oil deriving from the Sweet Pea (*Cyperus esculentus* L.) Marketed in Côte d'Ivoire

Aka Boigny Aurèle Ange[1], Konan N'Guessan Ysidor[1*], Coulibaly Adama[2], Chatigre Kouamé Olivier[1] and Biego Godi Henri[1]

[1]Laboratory of Biochemistry and Sciences of Food, Training and Research Unit of Biosciences, Félix Houphouët-Boigny University, 22 BP 582, Abidjan, Côte d'Ivoire.
[2]Training and Research Unit of Biological Sciences, Peleforo Gon Coulibaly University, Korhogo, Côte d'Ivoire.

Authors' contributions

Author BGH designed the study and supervised the overall work. Author ABAA wrote the protocol, fitted the data and wrote the first draft of the manuscript. Author KNY performed the statistical analysis, managed the literature, and checked the first draft of the manuscript and the revisions. Author CA assisted the experiments implementation and the literature searches. Author CKO gave expertise in results interpretations. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJBCRR/2016/28217
Editor(s):
(1) Kuo-Wei Lin, Department of Food and Nutrition Providence University, Taiwan.
Reviewers:
(1) Tijjani S. Imam, Bayero University, Kano, Nigeria.
(2) Tulay Aşkin Çelik, Adnan Menderes University, Turkey.
Complete Peer review History: http://www.sciencedomain.org/review-history/15878

Original Research Article

Received 9th July 2016
Accepted 10th August 2016
Published 22nd August 2016

ABSTRACT

Aims: To assess physico-chemical and nutritive traits in seeds and seed oil of the sweet pea marketed in Abidjan and consumed in Côte d'Ivoire.
Study Design: Pool of sweet pea seeds samples gathered from communal markets in District of Abidjan. Biochemical parameters investigated, and then sweet pea oil extracted from dried seeds and characterized for its main properties.
Place and Duration of Study: Laboratory of Biochemistry and Food Sciences, Department of Biochemistry, Biosciences Unit, between January and May 2015.

**Corresponding author: E-mail: haizykonan@yahoo.fr;*

Methodology: Sweet pea seeds gathered from nine communal wholesale markets considered in three communes of the District of Abidjan, three markets each commune. A pool of 5 kg of the overall sweet pea seeds samples was constituted. Then, biochemical parameters (moisture, proteins, lipids, ash, glucides, caloric value, and carbohydrates components) of the seeds samples were evaluated with official standard methods. Furthermore, the oil extracted from dried sweet pea seeds was characterized for properties: oil physicochemical quality (oil density, iodine, and peroxide and saponification indexes, acid value) and biochemical parameters (saturated and unsaturated fatty acids).

Results: The sweet pea seeds are with high contents of glucides (41.60±0.36 %), lipids (25.40±0.09%), and fibers (27.40±0.02%) and provide 8.25±0.01% of proteins. The most abundant glucides are starch (24.44±0.40 g/100 g) and sucrose (14.7±0.01%). The oil resulting from sweet pea seeds is richer in unsaturations, with iodine index of 130.9±0.88 g of I_2/100 g and unsaturated fatty acid content of 78.73%. This oil also reveals acceptable quality, with acid value of 1.18±0.05 mg KOH/g, peroxide index of 2.80±0.43 mEq O_2/kg, and contains secondary phytonutrients gathered within 0.96±0.012% of unsaponifiable compounds.

Conclusion: Thanks to the significant nutritive properties of the raw sweet pea seeds, and then the quality of their oil, especially the rather presence of unsaturated fatty acids, valorization of sweet pea seeds in foodstuffs could increase the profitability of this culture.

Keywords: Nutritive compounds; fatty acids; oil quality; sweet pea seeds.

1. INTRODUCTION

The sweet pea (*Cyperus esculentus* L) is a hardy and rhizomatous herbaceous in the plant systematic family of Cyperaceae. It accounts with common names of tuberous pea, ground kernel or striped nuts, and is originating from the Mediterranean basin [1,2]. With about 2,450 ha of acreages for 9,000 tons in 2012, Spain is the first producer of sweet pea seeds in the world, resulting in 3.3 billion euros of net incomes [3]. The sweet pea has been introduced in Africa by Arabs and is more cultivated in the Maghreb countries. It is also met in many countries of Western Africa [4] where Niger remains the top producer with 38,000 tons/year before Burkina Faso and Mali [5]. In Côte d'Ivoire, the sweet pea, locally named ‘’*tchongon*’’ in Malinké language, is cultivated in the savannah and the crops are primarily exported for Spain [5]. Indeed, the sweet pea seeds are raw material for the preparation of ‘’horchata de chufa’’, a typical milk of the Valencia region in Spain [6]. This drink deals with a significant interest for the general economy of the sweet pea seeds, from the production areas to the European continent [7]. The seeds are also used for oil production and the sweep pea seeds oil in richer in polyunsaturated fatty acids. Moreover, the fresh sweet pea seeds are regularly consumed by nurses and men for respective lactagenous and aphrodisiac properties [8,9]. In Africa, the sweet pea seeds are still used as food sets in several countries (Ghana, Togo and Senegal) especially in harshen seasons [10].

Several attempts were implemented upon the nutritive value of the sweet pea seeds cultivated in various countries. They show high percentages of proteins, fat content and low glycemic index carbohydrates. Such characters allowed promotion of the sweet pea in the food dietaries for people concerned with chronical pathologies related to diabetes and cardiovascular diseases [11,12]. However, the oil deriving from the sweet pea seeds is richer in omega-3 fatty acids [13,9]. So, it’s accounted with the reduction of the low density lipoproteins (LDL) and the rising of the high density lipoproteins (HDL), leading to reduction of the risk in occurrence of cardiovascular diseases [14]. It is also richer in vitamin E and antioxidants evidencing positive effects for the cellular membranes, the immune systems and the anti-radicalizing mechanisms [15].

In Côte d'Ivoire, the main studies about the sweet pea seeds are primarily related to the agronomic parameters [16,17]. In the general strategies to address nutrients deficiencies and regarding with the valorizations policies of the foodstuffs with social, cultural and nutritional interests, the sweet pea seeds could be considered as a bracing or a health food. This study is implemented to determine the nutritive characters of the seeds and the oil of the sweet pea consumed in Côte d’Ivoire.

2. MATERIALS AND METHODS

2.1 Plant Material

The plant material was constituted of fresh sweet pea seeds collected between January and May 2015 from several markets of the District of Abidjan, in Côte d'Ivoire. Specifically, the markets of Adjamé, Yopougon and Abobo respectively located at the center, the North-Western and the North-Eastern of Abidjan were considered.

2.2 Sampling

The sweet pea seeds were purchased from sedentary traders in 3 markets located in the communes of Adjamé, Yopougon and Abobo; 3 markets/commune. For each market, the sweet seeds were bought from 9 various female retailers at a rate of 10 kg per woman, leading to a total weight of 810 kg of seeds gathered and conveyed to laboratory for further investigations. Thus, a pool of 5 kg of sweet pea seeds was deducted after homogeneous mixture of the overall samples collected. This final amount was dried in an oven (Memmert, Germany) at 50 °C for 72 h. Then, the dried seeds were ground using a Heavy Duty machine. The crushed seeds were sealed and kept in a desiccator till analyses.

2.3 Assessment of Nutritive Compounds in Sweet Pea Seeds

Proximate components were analyzed using standard AOAC methods [18]. Thus, the sweet pea seeds moisture was deduced after further oven-drying (Memmert, Germany) at 105°C. The ash content has resulted from incineration of 5 g of dried sweet pea seeds sample at 550°C in an oven (PYROLABO, France) to constant mass. For crude fibers, 2 g of crushed sweet pea seeds samples were taken, then put into an extraction solution prepared with 0.25 M sulfuric acid and 0.31 M sodium hydroxide, undergoing intermittent boiling. After suction filtration, the insoluble residue was washed with hot water, oven-dried at 105ºC for 8 h, and then incinerated. The final residue led to the estimation of the crude fibers amount. The fibers, either soluble or insoluble, were quantified according to gravimetric enzymatic method [19]. The proteins contents were valued on the Kjeldahl total nitrogen method basis. The lipids contents were resulted from the extraction with solvent (hexane) and a Soxhlet device. The total glucides content and total caloric energy value were estimated using following formulas [20]:

- Total glucides content (%) = 100 – (% moisture + % proteins + % lipids + % ash) (1)

- Total caloric energy (%) = (% proteins x 4) + (% carbohydrates x 4) + (% lipids x 9) (2)

Starch content was also determined using iodine method of Jarvis and Walker [21]; and the total soluble carbohydrates measured out with the method of Dubois et al. [22] using phenol and sulfuric acid. Then, the reducing sugars were deducted from the method of Bernfeld et al. [23] using 3, 5-dinitrosallicyclic acid reagent. Prior to their quantification, soluble carbohydrates were extracted with ethanol, zinc acetate and oxalic acid [24]. The results of proteins, lipids, ashes, fibers, starch, total glucides, and total soluble and reducing carbohydrates contents were expressed on the dry weight basis.

2.4 Oligosaccharides from Carbohydrates of the Sweet Pea Seeds

The main simple carbohydrates components of the sweet pea seeds were identified using a High Performance liquid Ionic chromatography (HPIC) equipped with a DX600 unit (Dionex corp., Sunnyvale, CA) and a pulsed amperometric detector (Dionex ED50). Prior to analysis, samples of crushed sweet pea seeds have undergone a 1/1,000 dilution with ultrapure water (deionized). Then, they were filtered upon a micropore membrane (0.45-micron diameter) before injection on a 4 x 250 mm Dionex column (Carbocarp MA-1 model). The elution of the sugars was enhanced with a sodium hydroxide (NaOH) gradient, consisting in successive practicing of 0.8 M NaOH for 10 min, 0.6 M NaOH for 30 min and 0.8 M NaOH for 10 min once more, at a rate programme of 0.4 mL/min. An external mixture of standard carbohydrates compounds purchased from Sigma-corporation (Sigma Aldrich, USA) and taken at concentrations above their limit of quantification, was injected within 8 sets of sweet pea seeds samples, and also eluted. This accounted with drift coefficient and correction of the raw results before calculating the content of each carbohydrate molecule from the samples. The resulted chromatograms were analyzed with Chromoleon software version 6.11 (Dionex, USA). Each sample was analyzed in duplicate and the mean contents of carbohydrates elements were expressed in g/mL.

2.5 Characterization of the Oil deriving from Sweet Pea Seeds

2.5.1 Relative density

A 30 g test sample from the sweet pea seeds oil was solidified in a freezer. Then, the resulted butter was put into a test tube containing 300 mL of water. After stabilization of the water's level in the test tube, the final volume has been displayed. The experiment was carried out in triplicate, and the relative density of the butter is expressed as follows:

$$\text{Relative oil Density} = W/(V2-V1) \quad (3)$$

With: W, the oil weight; V1 and V2, the respective water volumes before and after addition of the butter.

2.5.2 Chemical parameters

Acid, peroxide, iodine, saponification and unsaponifiable parameters were determined from the dried sweet pea seeds oil using respective AFNOR standard methods of NF EN ISO 660 [25], NF T 60-220 [26], NF ISO 3961 [27], NF T 60-206 [28] and NF T 60-205 [29].

2.5.3 Fatty acid composition

The various fatty acids of the sweet pea seeds oil were highlighted according to AFNOR method [30]. This determination was achieved with a Gas Phase Chromatography device (Finnigan Focus GC System, Restek, France) coupled with a flame ionization detector, an injector and a digital integrator. The process was preceded by extraction of the fatty acids from triglycerides, and their conversion into methyl esters using chloroform-methanol solvent mixture. This operation used a silica capillary column (CP 88:60 Sil x 25 mm, Waters, USA) with helium as gas carrier at a programme of 20 mL/min. The column temperature was maintained at 100°C while the temperature of the injector and detector were both at 220°C. The calibration was made using an internal standard of methyl palmitate esters and the percentage of each fatty acid was obtained using the integrator (Azur Software: Thermo Electron Corporation, GC).

2.6 Statistical Analysis

The outcoming data were recorded with Excel program and then statistically treated using STATISTICA software (STATISTICA version 7.1). From each parameter assessed, the averages were calculated, and the homogeneity of the results was estimated according to the standard deviation and relative standard deviation.

3. RESULTS AND DISCUSSION

3.1 Proximate Nutritive Components of the Sweet Pea Seeds

The outcomes resulted from the physico-chemical parameters are recorded in Table 1. The mean moisture content of the studied sweet pea seeds is 5.29%. These seeds are also with averages of 8.25% of proteins content and 25.40% of fat content. Besides, they have more glucides content, with mean of 41.60%. Within glucides, mean contents of 27.40% and 24.40 g/100 g are respectively provided for fibers and starch, so as 19.40% of total ethanosoluble carbohydrates including 2.51% of reducing carbohydrates. From the energy-sources nutrients, the caloric energy value deriving with the sweet pea seeds is of 428.10 kcal/100 g. In addition, these seeds contain a mean percentage of 1.72% in ash.

Table 1. Main nutritive traits of the sweet pea seeds

Parameters	Contents	RSD* (%)
Moisture (%)	5.29 ± 0.03	0.57
Ash (%)	1.72 ± 0.36	20.93
Proteins (%)	8.25 ± 0.01	0.12
Fat (%)	25.40 ± 0.09	0.35
Total fibers (%)	27.40 ± 0.02	0.07
Total glucides (%)	41.60 ± 0.36	0.86
Total Caloric energy value (kcal/100 g)	428.10 ± 2.29	0.53
Starch content (g/100 g)	24.4± 0.04	0.16
Total ethanosoluble carbohydrates (%)	19.40 ± 0.11	0.57
Reducing carbohydrates (%)	2.51 ± 0.04	1.59

* *RSD: relative standard deviation*

3.2 Mono and Oligosaccharides of the Sweet Pea Seeds

The Table 2 highlights the main contents of the simple carbohydrates accounting with the glucides in the sweet pea seeds. Thus, a great presence of sucrose is recorded, with a mean

content of 14.7 g/100 g. These seeds also contain free residues of maltose, glucose and fructose in respective amounts of 0.50, 0.30 and 0.16 g/100 g.

Table 2. Contents of the main simple carbohydrates components of the sweet pea seeds

Carbohydrates elements	Contents (g/100 g)	RSD* (%)
Maltose	0.5± 0.005	1
Sucrose	14.7± 0.01	0.07
Glucose	0.3 ± 0.001	0.33
Fructose	0.16 ± 0.0028	1.75
Lactose	<LOQ	-
Xylose	<LOQ	-

** RSD: relative standard deviation; LOQ: limit of quantification*

3.3 Quality of the Oil Produced from the Sweet Pea Seeds

3.3.1 Physico-chemical parameters

The main traits of the oil deriving with the dried seeds of the sweet pea are showed in Table 3. The oil has a relative density of 0.93. It provides an acid value of 4.18 mg KOH/g, an iodine index of 130.9 g I2/100 g, a peroxide index of 15.80 mEq O_2/kg, a saponification index of 250.5 mg KOH/g and a mean percentage of 0.96% for the total unsaponifiable components.

Table 3. Values of the physico-chemical traits of the oil deriving from the sweet pea seeds

Parameters	Values	RSD* (%)
Relative density	0.930 ± 0.008	0.86
Acid value (mg KOH/g)	1.180 ± 0.048	4.07
Iodine index (g I_2/100 g)	130.9 ± 0.880	0.67
Peroxide index (mEq O_2/kg)	2.80 ± 0.426	15.21
Saponification index (mg KOH/g)	250.5 ± 0.504	0.2
Unsaponifiable content (%)	0.963 ± 0.012	1.25

** RSD: relative standard deviation*

3.3.2 Fatty acids of the sweet pea seeds oil

The sweet pea seeds oil is richer in unsaturated fatty acids (78.71%) than in saturated acids (21.21%), as shown in Table 4. The saturated fatty acids of this oil are mainly consisted of palmitic and stearic acids in respective percentages of 15.02% and 4.72%. Regarding with the unsaturated fatty acids, a higher presence of mono-unsaturations (65.65%) is revealed in Table 4. They are primarily consisted of oleic acid with mean content of 65.04%. Poly-unsaturated components gather 13.05% of the total fatty acids and are with the most significant presence of linoleic acid (12.83%) and 0.22% of linolenic acid (Table 4).

Table 4. Fatty acids composition of the oil deriving from the sweet pea seeds

Fatty acids	Contents (%)	RSD* (%)
Saturated fatty acids	**21.21±0.052**	**0.25**
Palmitic acid C16:0	15.02 ±0.016	0.11
Stearic acid C18:0	4.72 ±0.008	0.17
Arachidic acid C20:0	0.77 ±0.004	0.52
Behenic acid C22:0	0.43 ±0.008	1.86
Lignoceric acid C24:0	0.150 ±0.008	5.33
Margaric acid C17:0	0.12 ±0.008	6.67
Unsaturated fatty acids	**78.71**	
Mono-unsaturated fatty acids	**65.66 ± 0.071**	**0.11**
Oleic acid C18:1n9 cis	65.04 ±0.028	0.04
Palmitoleic acid C16:1	0.306 ±0.012	3.92
Eicosanoïc acid C20:1	0.296 ±0.012	4.05
Erucic acid C22:1n9	0.01 ±0.018	180.00
Nervonic acid C24:1	0.01 ±0.0001	1.00
Poly-unsaturated fatty acids	**13,05± 0,22**	**1.69**
Linoleic acid C18:2n6cis	12.83 ±0.214	1.67
Linolenic acid C18:3n3	0.22 ±0.008	3.64

** RSD: relative standard deviation*

4. DISCUSSION

With a mean content of 41.61%, the glucides appear as the main nutritive components in the sweet pea seeds. Such an observation was mentioned by Sanchez et al. [31] which reported 43% of glucides in the same raw food material. Other authors also confirmed the great glucide nature of these seeds, from about 44% [32]. The glucides components inner the sweet pea seeds are mainly consisting in food fibers (27.40%) and starch (24.44 g/100 g). With these contents, the studied seeds are obviously richer in starch than

many tubers such as potatoes which contain 18.17 g/100 g of starch [33]. Moreover, according to Adejuyitan et al. [34], significant intakes in starch and food fibers accounts with pre-biotic properties for intestinal microbes flora. The consumption of sweet pea seeds could contribute in prevention and treatment of pathologies like colon cancer. It could also reveal effective actions against cardiac, thrombosis and blood concerns related with obesity, diabetes and coronary disease risks, regarding with the conclusion of Chukwuma et al. [35]. In fact, Alegría-Torán [32] hypothesized on a probable high content of essential amino acid in the sweet pea seeds, specifically in arginine, supporting the production of insulin, which hormone is with a positive action in dropping of the blood glucose content.

The study showed 8.25% of proteins in the sweet pea seeds, corroborating the 8% reported by Kordylas [36]. That states on the lower proteins contents of the sweet pea seeds than the cowpea beans, one of the protein leguminous plants with more than 25% of proteins [37]. Nevertheless, Anderson et al. [38] and Borges et al. [39] emphasized the digestive enzyme characters of many proteins in this food resource, particularly for catalase, lipase and amylase. Such characteristics are significant assets for the consumption of the sweet pea seeds against gastro-intestinal and food digestion hazards. It is also duly right to state according to Bosch et al. [40] that proteins from sweet pea seeds could have better composition in essential amino acids above the indications of the FAO/WHO for fitting the needs from adult population.

The sweet pea seeds have a significant fat content (25.40 %), agreeing with values of 22.8 to 32.8 g/100 g found in other attempts upon the same raw material [41,42,43]. Thus, these seeds seem to be a better source of food lipids than many tubers such as potato and cassava whose consumption allows respective intakes of 2.5 and 5 mg/kg of body weight [44]. However, they remain less fatty than several other seeds such as nuts kernels and hazelnuts with respective 43.36% and 65.20% of lipids [45]. The main unsaturated fatty acids of the oil derived from dried sweet pea seeds are oleic acid (65.04%) and linoleic acid (12.83%). Fatty acids omega 9 and 6 endorse the sweet pea seeds oil into the group of fats recording obvious nutritive and healthy properties [46]. These oils involve in the reduction of the LDL cholesterol and triglycerides, whereas they induce increasing in the rate of blood HDL cholesterol or ‘’good cholesterol’’, limiting the risks of cardiovascular diseases.

Upon the assessed macronutrients basis, the sweet pea seeds are characterized by a high caloric energy value of 428.10 kcal/100 g. Still, a quite more caloric energy value of 524.6 kcal/100 g has been found by Oderinde [47] from the same seeds. This author also reported 1.86% of ash in the sweet pea seeds, close to the 1.72% resulted from the current study and forecasting a significant presence of minerals such as sodium, calcium, potassium, magnesium and zinc in the sweet pea seeds. In addition, a presence of secondary phytonutrients could be related with the 0.96% of unsaponifiable components recorded. Yeboah et al. [48] stated similar contents of 986.49 mg/100g for the total unsaponifiable content in sweet pea seeds, including sterols, polyphenols, saponins and carotenes.

5. CONCLUSION

This work was a contribution for valorization of the sweet pea seeds in Côte d’Ivoire. Quite more than a tuber grain, the sweet pea seed shows interesting nutritive characteristics. It’s a good source of caloric energy thanks to high contents in fat and glucides, with significant proteins content. It’s also an excellent source of food fibers. The sweet pea seeds oil is mainly consisted of unsaturated fatty acids such as oleic and linoleic acids, but records significant proportions of saturated fatty acids, specifically palmitic and stearic acids. Thus, the sweet pea seeds could point for excellent source of food nutrients to address the nutritional concerns for populations.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Odoemelan SA. Composition chimique et propriétés fonctionnelles de la farine de noix de conophor (*Tetracarpidium conophorum*). Int. J. Sci alimentaire. Technol. 2003;38:729-734.
2. Belewu MA, Belewu KY. Comparative physico-chemical evaluation of tiger nut,

Soybean and Coconut milk sources. Int. J. Agric. Biol. 2007;9:785-787.

3. CRDO. Consejo Regulador de la Denominacion d'Origen Chufa de Valencia; 2012.
   Available: http://www.chufadevalencia.org
4. Pascual B, Maroto JV, Lopez-Galarza S, Sanbautista A, Alagarda J. Chufa (*Cyperus esculentus* L. var. sativus Boeck): An unconventional crop studies related to applications and cultivation. Econo –Bot. 2000;54(4):439-48.
5. Alou AK. Plan d'affaire de la fédération SA'A de Maradi pour la commercialisation du souchet à l'export: Extrait Etude de Marché. 2008;4-14.
6. Beneyto H, Varo P, Guillem C, Murillo AD. Chemical characterization of the natural drink ''horchata de chufa" in the Alcoi´a and Comtat regions (Alicante). Alimentación, Equipos y Tecnologıa. 2000;19:99–101.
7. Rubert J, Sebastian N, Soriano JM, Soler C, Manes J. One-year monitoring of aflatoxins and ochratoxin A in tiger-nuts and their beverages. Food Chem. 2011;127:822–86.
8. Mason D. Tigernut ; 2005.
   Available:http://www.nvsuk.org.uk/growing show végétales 1/ tigernut php
9. Muhammad NO, Bamishaiye EI, Bamishaiye OM, Usman LA, Salawu MO, Nafiu MO, Oloyede OB. Physicochemical properties and fatty acid composition of *Cyperus esculentus* (tiger nut) tuber oil. Bioresearch Bulletin. 2011;5:51.
10. Omode A, Fatoki O, Olaogun KA. Physicochemical properties of some under-exploited and non-conventional oilseed. J. Agri. Food Chem. 1995;14:50-53.
11. Umerie SC, Enebeli JN. Malt caramel de la noix de *Cyperus esculentus*. J. Bio. Technol Resources. 1997;8:215-216.
12. Martiınez-VJF. Horchata y Salud: Posibles beneficios de la horchata de chufa en la prevencion de la arteriosclerosis. In: Jornada Chufa y Horchata: Tradicion y Salud, editor. Fundacion Valenciana de Estudios Avanzados. Valencia, Spain: Conselleria de Agricultura, Pesca y Alimentacion. 2003;87–94.
13. Eteshola E, Oraedu AC. Fatty acids composition of Tiger nut tubers (*Cyperus esculentus* L.), baobab seeds (*Adansonia digitata* L.) and their mixtures J. Am. Oil Chem Soc. 1996;73:255–257.
14. Belewu MA, Abodunrin OA. Preparation of Kunun from unexploited rich food source: Tiger nut (*Cyperus esculentus* L.). World Journal of Dairy Food Sci. 2006;1:19-21.
15. David AB. ''Tiger nut''. A Dictionary of Food and Nutrition; 2005.
    Encyclopedia.com.
    Available:http://www.encyclopedia.com/doc/1O39-tigernut.html (Accessed May, 2010)
16. Aké CB, Koné MW, Kamanzi AK, Aké M. Evaluation de quelques propriétés biologiques de produits de cueillette non ligneux vendus sur les marchés d'Abidjan et ses environs. Pharm. Med. Trad. 2006;XIV:1-17.
17. Koffi N, Kouassi KE, Tiébré MS. Plante utilisée dans le traitement des troubles gynéco-obstétriques par les peuples Abbey et Krobou d'Agboville (Côte d'Ivoire). Phytothérapie. 2009;7:262-274.
18. AOAC. Official Methods of Analysis of the Association of Analytical Chemists. 17th Edition. Washington DC, USA; 2000.
19. Prosky L, Asp NG, Schweizer TF, De Vries JW, Furda I. Determination of insoluble and soluble dietary fiber in foods and food products: collaborative study. Journal of AOAC International. 1992;75(2):360-367.
20. FAO. Food energy-methods of analysis and conversion factors. Food and Agriculture Organization, Ed, Rome, Italy. 2002;97.
21. Jarvis, Walker. Simultaneous, rapid, spectrophotometric determination of total starch, amylose and amylopectin. J Sci Food Agric. 1993;63(1):53-57.
22. Dubois M, Gilles K, Hamilton JK, Rebers PA, Smith S. Colorimetric methods for determination of sugar and related substances. Anal Chem. 1956;28:350-356.
23. Bernfeld P. Amylase α and β. In S Colowick & NO Kaplan Eds. Method in Enzymology. 1955;1:149-158.
24. Agbo N, Soumanou M, Yao K. Nouvelles techniques de conservation de la banane plantain en milieu rural avec de la matière végétale. Sciences des Aliments. 1996;16:607-621.
25. AFNOR NF EN ISO 660. Détermination de l'indice d'acide et de l'acidité. Association

Française de Normalisation, Paris, France; 1999.

26. AFNOR NF T 60-220. Détermination de l'indice de péroxyde. Association Française de Normalisation, Paris, France; 1995.
27. AFNOR NF ISO 3961. Détermination de l'indice d'iode. Association Française de Normalisation, Paris, France; 2013.
28. AFNOR NF T 60-206. Détermination de l'indice de saponification. Association Française de Normalisation, Paris, France; 1990.
29. AFNOR NF T 60-205. Vegetable and animal fats and oils-Determination of unsaponifiable matter. Association Française de Normalisation, Paris, France; 1975.
30. AFNOR NF ISO 17059. Graines de triglycérides pour analyse par chromatographie en phase gazeuse (méthode rapide). Association Française de Normalisation, VO3-935 PR, Paris, France; 2005.
31. Sanchez-Zapata E, Fernandez-Lopez J, Pérez-Alvarez JA. Tigernut (*Cyperus esculentus* L.) commercialization; Health Aspects, Composition, Properties and Food application. Comprehensive Review in Foods Science and Food Safety. 2012;11:366-376.
32. Alegria-Torán A, Farré-Rovira R. Horchata y salud: Aspectos nutricionales y dietéticos. In: Fundación Valencia na de Estudios Avanzados, editor. Jornada Chufa y Horchata: Tradición y Salud. Valencia, Spain: Consellería de Agricultura, Pesca y Alimentación. 2003;55–70.
33. Coskuner Y, Ercan R, Karababa E, Nazlican AN. Physical and chemical properties of chufa (*Cyperus esculentus* L.) tubers grown in the Cukurova region of Turkey. J Sci Food Agri. 2002;82:625–631.
34. Adejuyitan, JA, Otunola ET, Akande EA, Bolarinwa IF, Oladokun FM. Some Physicochemical properties of flour obtained from fermentation of tiger nut (*Cyperus esculentus* L.) sourced from a market in Ogbomoso, Nigeria. Afr. J. Food Sci. 2009;3:51-55.
35. Chukwuma ER, Obioma N, Christopher OI. The phytochemical composition and some biochemical effects of Nigerian tigernut (*Cyperus esculentus* L.) tuber. Pak J Nutr. 2010;9(7):709–715.
36. Kordylas JM. Processing and preservation of tropical and subtropical food. J. Agri. Food Tech. 1990;13:28-40.
37. Mahan MR, Konan NY, Sidibé D, Coulibaly A, Ezoua P, Chatigre KO, Biégo GHM. Nutritive compounds from leaves of *Moringa oleifera* L. and beans of *Vigna unguiculata* W. for improvement of the meal deriving with new shoots of *Borassus aethiopum* M. in Côte d'Ivoire. International Journal of Environmental & Agriculture Research. 2016;2(6):64-74.
38. Anderson JW, Baird P, Davis RH, Ferreri S, Knudtson M, Koraym A. Health benefits of dietary fiber. Nutr Rev. 2009;67:188–205.
39. Borges O, Gonçalves B, Sgeoeiro L, Correia P, Silva A. Nutritional quality of chestnut cultivars from Portugal. Food Chem. 2008;106:976–984.
40. Bosch L, Alegrıa-Toran A, Farre-Rovira R. RP-HPLC determination of tiger nut and orgeat amino acid contents. Food Sci Technol Intl. 2005;11:33–40.
41. Mokady SH, Dolev A. Nutritional evaluation of tubers of (*Cyperus esculentus* L.). J Sci Food Agric. 1970;21: 211–214.
42. Addy EO, Eteshola E. Nutritive value of mixture of tiger nut tubers (*Cyperus esculentus* L.) and baobab seeds (*Adansonia digitata* L.). J. Sci. Food Agric. 1984;35:437-440.
43. Temple VJ, Ojobe TO, Kapu MM. Chemical analysis of Tiger nut (*Cyperus esculentus* L.). J. Sci Agric. 1989;50:261-263.
44. Maieves HA, Cardoso OD, Bernardo C, Oliveira MCM, Amante ER. Microscopy and texture of raw and cooked cassava (*Manihot esculenta* Crantz) roots. J Texture Stud. 2012;43(2):164–173.
45. Venkatachalam M, Sathe SK. Chemical composition of selected edible nut seeds. J Agric Food Chem. 2006;54:4705–4714.
46. Dubois V, Breton S, Linder M, Fanni J, Parmentier M. Fatty acid profiles of 80 vegetable oils with regard to their nutritional potential. Eur J Lipid Sci Technol. 2007;109:720–732.

47. Oderinde RA, Tairu OA. Evaluation of the properties of yellow nut sedge (*Cyperus esculentus* L.) tuber oil. Food Chem. 1988;28:233–237.

48. Yeboah SO, Mitei YC, Wessjohann L, Schmidt J. Compositional and structural studies of the oils from two edible seeds: Tiger nut (*Cyperus esculentus* L.) and asiato (*Pachira insignis*) from Ghana. Food Res Inter; 2011.

DOI: 10.1016/j.foodres. 2011.06.306.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/15878