OPEN ACCESS
Scholars International Journal of Chemistry and Material Sciences
Abbreviated Key Title: Sch Int J Chem Mater Sci
ISSN 2616-8669 (Print) |ISSN 2617-6556 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com/journal/sijcms/home

Original Research Article

Physical Parameters of African Hazelnut (*Coula edulis* B.) and Effect of Cooking Time on Physicochemical Properties

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| **Received:** 13.03.2019 | **Accepted:** 22.03.2019 | **Published:** 31.03.2019
DOI:10.36348/sijcms.2019.v02i03.001

Abstract

This study was conducted to determine the physical characteristics of the hazelnut in two forms and to evaluate the impact of cooking on the physicochemical properties. The results showed that the weight of the African hazelnuts ranged from 5.03±0.81 to 22.15±3.93 g, lengths ranging from 2.0±0.07 to 3.56±0.15 cm, widths from 3.29±0.31 to 3.29±0.31 cm. Lengths and widths of whole fruits and seeds showed no significant differences ($p < 0.05$). The most dominant parameters are carbohydrates, fats and proteins. Fat (33.92±6.02-31.73±3.08), protein (11.29±2.15-10.20±2.28), fiber (2.37±0.67-1.45±0.05) and dry matter (94.92±0.47-93.63±1.91) contents (%) decreased significantly ($p < 0.05$) after cooking, while carbohydrates (52.15±4.37-55.75± 5.62) reducing sugars (1.25±0.11-2.08±0.35) and total sugars (5.58 ± 0.87 -6.15±1.3) contents increased. Mineral composition of African hazelnut flours is dominated by potassium, magnesium, phosphorus and calcium. The potassium (5582.15±58-5314.65±204 mg/Kg), magnesium (5243.8±226 - 4003.8±177 mg/Kg), manganese (31.53±0.8 -30.93±0.7 mg/Kg), iron (30.33±0.45-26.25±0.32 mg/Kg), calcium (1925±63-1167.7 ±18 mg/Kg) and sodium (255±3.54-241.7±1.92 mg/Kg) contents decreased after cooking while zinc content (21.47±1.27-241.7 ± 1.92 mg/Kg) increased.
Keywords: Cooked, Flour, African hazelnut, Physico-chemical, physics parameters.

INTRODUCTION

In africa, forest products have for centuries played an important role in commercial food production. They still contribute to poverty reduction and food security for forest dwellers in developing countries. Indeed, many plant extracts of natural origin usefully complement agricultural production as emphasized [1]. Rural african communities have excellent knowledge of traditional value and properties of many plant species still underutilized. These are wild or cultivated plants whose potential utility have been little exploited commercially, but are a support for economic survival and food for local populations [2]. The lack of scientific and technical information (distribution, ecology, uses, domestication, improvement of production, harvesting, processing and trade opportunities) on these neglected resources is probably the biggest constraints to their development [3]. However, it is pertinent to acknowledge the contributions of these neglected resources to the household economy, food security, national economy and some ecological objectives such as the conservation of biodiversity [4]. This is the case of *coula edulis*, a lesser known non timber forest product which has not yet been the subject of scientific studies. The tree belongs to the family olacaceae which comprised of about 250 species [5]. *Coula edulis* is a medium sized, evergreen tree growing to a height of 25-38m with dense crown that can cast deep shade. The plant flowers between january and may [6]. They can grow under plantation condition as a timber plant. [6] also described the fruit as a nut, ellipsoidal in shape being about 3-4cm long with flesh 5-6mm thick surrounding the kernel. *Coula* edulis is a tree in the genus *coula*, native to tropical western africa from sierra leone to angola. It is plentiful in the democratic republic of congo, nigeria and sierra leone. It prefers tropical regions and it is tolerant of light shade. It can be found in the top canopy of forest as well as the lower storey and has no special soil requirements [7]. The main period of flowering is largely dry season from june to august in cote d'ivoire. African hazelnut are usually found under the mother trees. The kernel shell is extremely hard and makes germination difficult [7]. Indicated that germination is very slow and staggered (3 to 24 months). African hazelnut are used in a variety of ways; it can be boiled, roasted and fermented, can be used in recipes and mixed with meats [8]. It is also a source of cooking oil and ground flour [6]. African hazelnuts are rich in linoleic acid, and in consequence contribute poly-unsaturated fatty acids [9]. Coula edulis is a lesser known tree nut which is underutilized despite the nutritional benefits associated with tree nuts consumption. They are wild nut and are not commonly cultivated in our present environment. Thus, their potential utility has not been exploited commercially or at home use, resulting to no known products made from them. Germination of african hazelnut (*coula edulis*) is very low and staggered (3 to 24 months) with a germination rate considered very low (10 to 20%). The difficulty of germination is one of the main causes of the absence of local agro forestry systems [8]. African hazelnut (*coula edulis*) is the one variety grown in cote d'ivoire.

The current study investigates the physical and physicochimical parameters of African hazelnut (*Coula edulis*) and the impact of cooking.

MATERIALS AND METHODS

Materials

Hazelnuts *Coula edulis* (Figures 1 and 2) used for this work were randomly harvested at maturity from a farm in Azaguié (South, Côte d'Ivoire). The raw materials were physically examined to ensure disease-free. Then, they were immediately transported to the Laboratory of Biocatalysis and Bioprocesses (Abidjan, Côte d'Ivoire). All the chemicals, reagents and solvents used in the experiments were of analytical grade and were products of Sigma Chemical Co. (St. Louis, MO).

Fig-1: African hazelnuts (*Coula edulis* B.)

Fig-2: African hazelnuts (*Coula edulis* B.) seeds

METHODS

Physical analyses

Two hundred african hazelnuts (*coula edulis*) collected were divided into two lots of one hundred hazelnuts. Lot one consists of whole hazelnuts (figure 1) and lot two of hazelnut seeds (figure 2). linear dimensions, i.e. length (l), width (w) were measured by using a digital caliper (inox hardened) with a sensitivity of 0.01 mm. african hazelnuts (fruit and seeds) weight were measured by using a digital balance (sartorius) with a sensitivity of 0.001 g.

Processing of *Coula edulis* into flours

Five (5) kg of hazelnuts (*Coula edulis*) were peeled with a stainless knife to obtain hulls. These shells were broken with this same knife to extract the seeds. Seeds obtained were washed with distilled water, wrung on wattman paper (number one) and weighed. They were split into two lots of more or less equal masses. The seeds of batch 1 (1.5 kg) remained raw. The seeds of batch 2 (1.5 kg) were boiled with distilled water (two liters) for 20 min on a SCHOTT heating plate. All the seeds of each batch were then oven-dried

(55 °C, 48 hours). The dry seeds of each lot were crushed with a porcelain mortar and then ground in a MOULINEX mixer. The flours obtained were sieved using an AFNOR sieve with a mesh size of 250 µm (Figure-3).

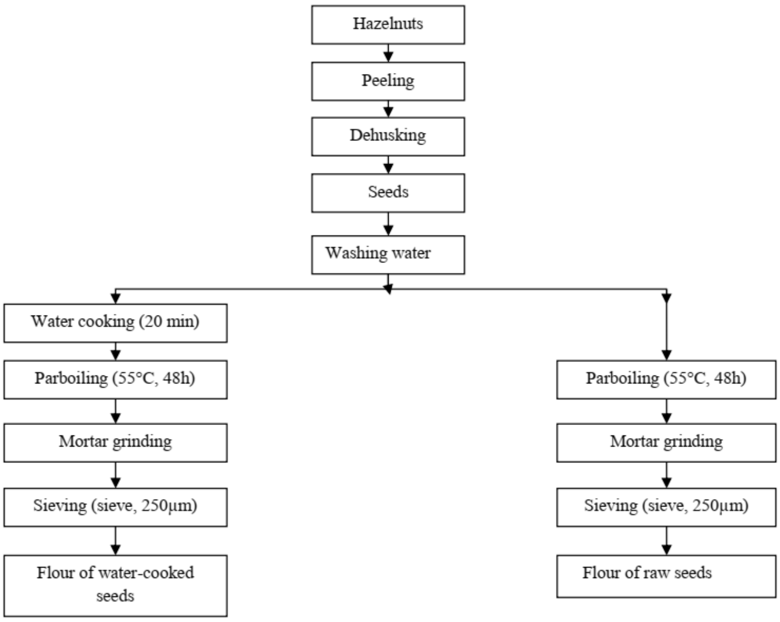

Fig-3: Manufacturing processes for *Coula edulis* seeds flours

Proximate composition

The dry matters contents of the flours from African hazelnuts (Coula edulis) were determined by drying in an oven at 105ºC during 24 h to constant weight [10]. Fat contents were determined by continuous extraction in a Soxhlet apparatus for 8 h using hexane as solvent [10] .The protein contents were calculated from nitrogen contents (N x 6.25) obtained using the Kjeldahl method [10]. The crude fiber contents were determined according to standard method [10]. The total ash contents were determined by incinerating flour (3 g) in a furnace at 550ºC for 6 h, then weighing the residue after cooling to room temperature in a desiccator [10]. The method [11] was used for the total sugar contents analysis. The reducing sugar contents were determined [12]. The method of extraction of hazelnut starch was carried out [13, 14]. The carbohydrate contents were determined by deference that is by deducting the mean values of other parameters that were determined from 100. Therefore % carbohydrate = 100-(% moisture +% crude protein + % crude fat + crude fibre + % ash). Caloric energy was calculated according to Atwater general factor system [15].

Mineral Composition

The minerals, such as calcium, manganese, iron, magnesium, sodium, potassium and zinc of flours from African hazelnut (*Coula edulis*) were analyzed [16] with an atomic absorption spectrophotometer (Pye-Unicam 969, Cambridge, UK). Phosphorus contents were estimated colorimetrically (UV-visible spectrophotometer, JASCO V-530, Model Tudc 12 B4, Japan Servo Co. Ltd., Indonesia), using potassium dihydrogen phosphate as the standard [17].

Statistical Methods

All the data were analyzed using the SPSS 20 statistical software for analysis of variance using ANOVA and Duncan's least significant difference (LSD at $p < 0.05$) for statistical significance. 3 duplicates with a replicate were considered in this research, and data was reported as the mean ± standard error of the mean.

RESULTS AND DISCUSSIONS

Physical parameters

The mean values of dimensions (Length, width) and weight of African hazelnut (*Coula edulis*) are given in Table-1. Linear dimensions in hazelnuts can be useful for aperture size of machines, particularly in separation, and may also be useful in estimating the size of machine components. The whole fruit and seeds of *Coula edulis* are larger in size than the same organs of hazelnuts *Corylus avellana* [18-20]. Indeed *Corylus avellana* seeds are 1.50cm (length) and 1.39cm (width) [21]. *Corylus avellana* fruits are 1.98 cm (length) and 1.81 cm (width) [19]. The weight (g), length (cm) and width (cm) of four major commercial turkish hazelnuts varieties varied from 1.483 to 2.134, 1.56 to 1.98, 1.66 to 1.89 respectively [21]. These differences could be the result of the individual properties of hazelnut varieties and environmental and growth conditions (Akinci & Ozdemir, 2004). High dissimilarity among our results and results observed by above authors about European hazelnuts (*Corylus* sp.) could be connected with genetic differences, pedo-climatic conditions and cultural practices [22-24]. The knowledge of physical properties of agricultural products is very essential for the design of suitable machine and equipment for the production, handling, processing and storage of these products [25].

Table-1: Physical parameters of African hazelnut (*Coula edulis* B.)

Physical parameters	African hazelnut (*Coula edulis* B.)	
	Shapes	Raw
Weight (g)	Whole fruit	22.15±3.93[a]
	Seed	5.03±0.81[b]
Lenght (cm)	Whole fruit	3.56±0.15[a]
	Seed	2.0±0.07[b]
Width (cm)	Whole fruit	3.29±0.31[a]
	Seed	1.97±0.07[b]

Data are means ± SD of triplicate determinations

Physicochemical Properties

The physicochemical properties of *Coula edulis* flours are given in table 2. When fruits or vegetables are heat treated, several reactions, both chemical and enzymatic occur. The high dry matter content would reflect low content of moisture that might be favourable for prolonged storage of hazelnut seed flours. This result indicated lower content of water activity in cooked samples, which plays a vital role in food storage [26]. Cooking caused a significant decrease in dry mater content for the seeds. Similar results were obtained [27]. These decreases might be attributed to their diffusion into cooking water [28].

Fat content of *Coula edulis* seeds flours decreased from 33.92±6.02 to 31.73±3.08 during cooking. These fat values were below 50%, a content corresponding to the studies of some researchers on European hazelnuts (*Corylus* sp.) [29-33]. The decrease in the fat content might be due to an increase in lipase activity and denaturation of the lipid fraction during the preservation treatment [34]. The decrease in lipids might be due to the denaturation and breakdown of the lipids into glycerol and fatty acids [35]. Diets high in hazelnuts and other tree nuts resulted in lowered LDL cholesterol reduced inflammation and improved blood lipids [36, 37].

Protein content of Coula edulis flours ranged from 11.29±2.15 to 10.20±2.28 %. These values are lower than the values of English walnut (15.23%) and hazelnut (14.95%) [38]. The nutritional composition of foods generally differ significantly depending upon variety and geographical origin [39]. Storage and method of processing/sample preparation [40]. Thus Coula edulis can contribute significantly as part of the recommended human daily protein requirement of (10-30g) [41]. Decrease in protein contents (from 11.29±2.15 to 10.20±2.28) of African hazelnuts (*Coula edulis* B.) seeds flours after cooking could be explained by solubilization of soluble protein fractions in cooking in water [42]. This result agreed with a decrease of the protein content in some cooked vegetables [42].

Ash content gives an indication of minerals present in a particular food sample and it is very important in many biochemical reactions which aid physiological functioning of major metabolic processes in the human body [43]. Ash content in Coula edulis flours ranged from 2.21±0.87 to 2.10±0.38 %. Decrease in ash contents may be due to leaching of minerals in boiling water.

Reducing sugars content in *Coula edulis* flours (1.25±0.11-2.08±0.35 %) was found to be higher than those of several tropical yam flours (0.12-1.03%) [44]. It has been suggested that reducing sugars in flour may cause caking and damping during their storage because of sugars hygroscopic property. Indeed, sugars may be desirable in bakery products like bread and cake where the tenderizing effects positively affect texture and where sugars serve as substrate for fermentation of the dough [45].

As shown in Table-2, carbohydrate values of *Coula edulis* seeds flours ranged from 52.15±4.37 to 55.75±5.62 % and show to be the most important biochemical component. The high carbohydrates contents in *Coula edulis* flours makes it an energy food. The carbohydrate contents of flour increased significantly ($p \leq 0.05$) with cooking time. This may have been due to the fact that carbohydrates may have absorbed water to bulk up via cross-linking reaction probably induced by heat generated by cooking [46].

The increase in carbohydrate content with cooking might be due to the destruction of hazelnuts cell walls that causes an increase in solubility of carbohydrates in water. A smaller increase of carbohydrates in boiled sample might be due to the fact that when the cell walls are destroyed, the carbohydrates might have leached into the boiling water before the extraction for analysis.

Starch content of Coula edulis flours are similar to various tubers and starchy roots [13] on taro (*Colocassia esculenta*) starches and various tropical food crops between 96.8% and 97.7% respectively [47, 48].

Energies values of *Coula edulis* flours (559.04-548.97 Cal/100g) are higher than those of yam (*Dioscorea* spp) tubers (373-391 Cal/100g), cassava (*Manihot esculenta*) roots (376-391 cal/100 g) [49], sweet potato tubers (366-370 Cal/100 g) [49] and taro (*Colocassia esculenta*) (385-390 Cal/100 g) [47].

Table-2 : Physicochemical properties of African hazelnut (*Coula edulis* B.) flours

Properties (%)	African hazelnut (*Coula edulis* B.) flours	
	Raw	Cooked (20 min)
Dry matter	94.92±0.47[b]	93.63±1.91[b]
Fat	33.92±6.02[a]	31.73±3.08[a]
Protein	11.29±2.15[a]	10.20±2.28[b]
Ash	2.21±0.87[a]	2.10±0.38[a]
Carbohydrate	52.15±4.37[a]	55.75±5.62[a]
Starch	44.51±4.05[a]	44.38±3.65[a]
Total sugars	5.58±0.87[a]	6,15±1.3[a]
Reducing sugars	1.25±0.11[a]	2.08±0.35[b]
Fiber	2.37±0.67[a]	1.45±0.05[b]
Energy value (Kcal/100g)	559.04	548.97

Data are means ± SD of triplicate determinations

Mineral Composition

The result presented in Table-3 showed the mineral composition of *Coula edulis* flours (raw and boiling). Minerals are important to diet because of their physiological and metabolic function in the body. The mineral elements found in this study are similar to Turkish hazelnut varieties [51-53, 28].

Hazelnuts *Coula edulis* are also a great source of magnesium (5243.8±226 and 5314.65±204 mg/Kg), which has been proven to decrease the risk for diabetes and helps to regulate the balance of calcium and potassium and is crucial to blood pressure [54]. Proven to improve glucose intolerance, hazelnuts' high levels of manganese are also helpful in the fight against diabetes when used as a diet supplement [55].

Decrease of potassium (from 5582.15±58 to 5314.65±204 mg/Kg) and magnesium (from 5243.8±226 to 4003.8±177 mg/Kg) contents may be because of its leaching into the water during boiling [56].

Presence of Fe, Zn in hazeluts flours make hazelnut interesting for human diets, and especially for electrolyte balance [57]. The ratio of K/Na in any food is an important factor in prevention of hypertension and arteriosclerosis, with K depresses and Na enhances blood pressure [58]. The ratio of K/Na (21.89 and 21.98) in Coula edulis flours were higher than in the fruits of P.roxburghii (17.68), *T.bellirica* (15.82) and compared well with some wild fruits such as *B.sapida* [56]. Therefore consumption of hazelnuts Coula edulis would probably reduce high blood pressure diseases because their K/Na is greater than one [59].

Table-3: Mineral composition of African hazelnut (*Coula edulis*) flours

Parameters (mg/Kg)	African hazelnut (*Coula edulis* B.) flours	
	Raw	Cooked (20 min)
Phosphore	4143±81[a]	4150±146[a]
Potassium	5582.15±58[a]	5314.65±204[b]
Magnesium	5243.8±226[a]	4003.8±177[b]
Manganese	31.53±0.8[a]	30.93±0.7[b]
Fer	30.33±0.45[a]	26.25±0.32[b]
Calcium	1925±63[a]	1167.7±18[b]
Zinc	21.47±1.27[b]	22.83±0.78[a]
Sodium	255±3.54[a]	241.7±1.92[b]
K/Na	21.89	21.98

REFERENCES

1. Bahuchet, S. (2000). Five years in Central Africa: a forest peoples States In: Bahuchet, S and Maret, P; editors. The peoples of the tropical forests. *Flight*, 3:5-21.
2. Gandari, J. (2008). Indigenous fruits. *Spore*, 136:8-10.
3. Zohoun, G. (2002). The use of forest products (NTFPs) in the context of sustainable forest management in Benin. *The flamboyant*, 55:13-18.

4. FAO. (2010). The potential for industrial processing of sorghum for baking and allied food industries in Africa. Report of the regional workshop on composite flours, Sham bat, Soudan, Rome, 32. www.agrosciencejournal.com/public/agro9-2.pdf.
5. Mabberley, D. J. (1997). The plant Book: A portable dictionary of the vascular plants. 2 nd edn., Cambridge University press, UK. http://www.cambridge.org/us/academic/subject/.
6. Alan, D. (1999). The Oxford companion to food. 1 st edition, Oxford University press. Gabon Nut, London, 328.
7. Orwa, C., Mutua, A., Kindt, R., Jamnadass, R., & Simons, A. (2009). Agroforestree Database: A tree Reference and selection guide version 4.0. http://www.worldagroforestry.org/af/treedb/
8. Bonnéhin, L. (2000). *Domestication paysanne des arbres fruitiers forestiers: cas de Coula edulis Bail, Olacaceae, et de Tieghemella heckelii Pierre ex A. Chev., Sapotaceae, autour du Parc National de Taï, Côte d'Ivoire*.
9. Ekissi, E. S. G., Fankroma, M. T. K., Koffi, B. K. P., & Kouamé, L. P. (2016). Physico-chemical properties, fatty acid composition and storage stability of Coula edulis Bail. seed oil from Côte d'Ivoire. *International Journal of Biosciences*, 8(5), 190-201.
10. AOAC. (1990). Official Methods of Analysis. 1990.15th Edition., Association of Official Analytical Chemistry, Washington DC.
11. Dubois, M., Gilles, K. A., Hamilton, J. K., Rebers, P. T., & Smith, F. (1956). Colorimetric method for determination of sugars and related substances. *Analytical chemistry*, *28*(3), 350-356.
12. Bernfeld, P. (1955). Amylase β and α (Assay method), in methods in enzymology I, Colowick and Kaplan, Ed., Academic press, New York, 149-154.
13. Delpeuch, F., Favier, J. C., & Charbonnière, R. (1979). Caractéristiques des amidons des plantes alimentaires tropicales. *Annales des Techniques Agricoles*, 27(4): 809-826.
14. Amani, N. G. (1993). *Contribution à l'étude des tubercules de taro (Xanthosoma sagittifolium L. Schot.): Evolution des propriétés physicochimique de l'amidon au cours des traitements technologique* (Doctoral dissertation, Thèse de doctorat 3ème cycle, université d'Abidjan 117 p).
15. FAO. (2004). Energy in human nutrition. Report of a Joint FAO/WHO/UNU Expert Consultation. FAO Food and Nutrition Paper No. 78. Rome.
16. Onwuliri, V. A. (1992). Proximate and elemental composition of Bryophyllum pinnatum (Lim). *Med. Sci. Res.*, *20*, 103-104.
17. AOAC. (1980). Official methods of analysis of the Association of Official Analytical Chemists, 13th edition, 734-778.
18. Serra, B. J., & Ventura, C. F. (1992). Caractéristiques physiques des principales variétés (*Corylus avellana* L.) produites dans la province de Tarrapona Espagne. *Industrie Alimentaire et Agricole*, 109: 23-27.
19. Özdemir, F., Topuz, A., Doğan, Ü., & Karkacıer, M. (1998). Fındık çeşitlerinin bazı fiziksel ve kimyasal özellikleri. *Gida/The Journal Of Food*, *23*(1), 37-41.
20. Aydin, C. (2002). Physical properties of hazelnut. *Biosystems Engineering*, 82(3): 297-303.
21. Ozdemir, F., & Akinci, I. (2004). Physical and nutritional properties of four major commercial Turkish hazelnut varieties. *Journal of Food Engineering*, *63*(3), 341-347.
22. Bostan, S. Z., & İSLAM, A. (1999). Some Nut Characteristics and Variatin of These Characteristics Within Hazelnut Cultivar Palaz. *Turkish Journal of Agriculture and Forestry*, *23*(4), 367-370.
23. Silva, A. P., Santos, A., Cavalheiro, J., Ribeiro, C., Santos, F., & Gonçalves, B. (2007). Fruit chemical composition of hazelnut cultivars grown in Portugal. *Journal of Applied Horticulture*, *9*(2), 157-161.
24. Solar, A., & Štampar, F. (2009). Performance of hazelnut cultivars from Oregon in northeastern Slovenia. *HortTechnology*, *19*(3), 653-659.
25. Gao, X., Ohlander, M., Jeppsson, N., Björk, L., & Trajkovski, V. (2000). Changes in antioxidant effects and their relationship to phytonutrients in fruits of sea buckthorn (Hippophae rhamnoides L.) during maturation. *Journal of Agricultural and Food Chemistry*, *48*(5), 1485-1490.
26. Shah, S., Sharma, A., & Gupta, M. N. (2004). Extraction of oil from Jatropha curcas L. seed kernels by enzyme assisted three phase partitioning. *Industrial crops and products*, *20*(3), 275-279.
27. Hefnawy, T. H. (2011). Effect of processing methods on nutritional composition and anti-nutritional factors in lentils (Lens culinaris). *Annals of Agricultural Sciences*, *56*(2), 57-61.
28. Ozdemir, M. (2001). Evaluation of new Turkish hybrid hazelnut (Corylus avellana L.) varieties: fatty acid composition, α-tocopherol content, mineral composition and stability. *Food Chemistry*, *73*, 411-415.
29. Alasalvar, C., Shahidi, F., Ohshima, T., Wanasundara, U., Yurttas, H. C., Liyanapathirana, C. M., & Rodrigues, F. B. (2003). Turkish Tombul hazelnut (Corylus avellana L.). 2. Lipid characteristics and oxidative stability. *Journal of Agricultural and Food Chemistry*, *51*(13), 3797-3805.
30. Amaral, J. S., Casal, S., Alves, M. R., Seabra, R. M., & Oliveira, B. P. (2006). Tocopherol and tocotrienol content of hazelnut cultivars grown in Portugal. *Journal of agricultural and food chemistry*, *54*(4), 1329-1336.
31. Köksal, A. İ., Artik, N., Şimşek, A., & Güneş, N. (2006). Nutrient composition of hazelnut (Corylus

avellana L.) varieties cultivated in Turkey. *Food Chemistry*, *99*(3), 509-515.
32. Pereira, J. A., Oliveira, I., Sousa, A., Ferreira, I. C., Bento, A., & Estevinho, L. (2008). Bioactive properties and chemical composition of six walnut (Juglans regia L.) cultivars. *Food and chemical toxicology*, *46*(6), 2103-2111.
33. Reid, T., Munyanyi, M., & Mduluza, T. (2017). Effect of cooking and preservation on nutritional and phytochemical composition of the mushroom Amanita zambiana. *Food science & nutrition*, *5*(3), 538-544.
34. Igbedioh, S. O., Olugbemi, K. T., & Akpapunam, M. A. (1994). Effects of processing methods on phytic acid level and some constituents in bambara groundnut (Vigna subterranea) and pigeon pea (Cajanus cajan). *Food Chemistry*, *50*(2), 147-151.
35. Mercanlıgil, S. M., Arslan, P., Alasalvar, C., Okut, E., Akgül, E., Pınar, A., ... & Shahidi, F. (2007). Effects of hazelnut-enriched diet on plasma cholesterol and lipoprotein profiles in hypercholesterolemic adult men. *European journal of clinical nutrition*, *61*(2), 212-220.
36. Tey, S. L., Delahunty, C., Gray, A., Chisholm, A., & Brown, R. C. (2015). Effects of regular consumption of different forms of almonds and hazelnuts on acceptance and blood lipids. *European journal of nutrition*, *54*(3), 483-487.
37. USDA. (2010). United states Department of Agriculture, National nutrient database for standard reference, Agricultural Research Service SR23. http://www.ars.usda.gov/services/docs.
38. Ajah, P. O., & Madubuike, F. N. (1997). The proximate composition of some tropical legume seeds grown in two states in Nigeria. *Food chemistry*, *59*(3), 361-365.
39. Aremu, C. Y. (1993). Nutrient composition of corn OGI prepared by a slightly modified traditional technique. *Food chemistry*, *46*(3), 231-233.
40. USDA. (2010). United states Department of Agriculture, National nutrient database for standard reference, Agricultural Research Service SR23. http://www.ars.usda.gov/services/docs.htm
41. Medoua, N. G. J. M. (2005). Nutritional and technological potentials of hardened tubers of yam Dioscorea dumetorum (Kunth) pax: study of curing post-harvest and processing conditions hardened tubers flour - Doctoral Thesis / PhD., 254. French.
42. Bamishaiye, E. I., Olayemi, F. F., & Bamishaiye, O. M. (2011). Effects of boiling time on mineral and vitamin C content of three varieties of Hibiscus sabdriffa drink in Nigeria. *World Journal of Agricultural Sciences*, *7*(1), 62-67.
43. Koné, D., Koné, F., M., T. Djè, K., M., Dabonné S., & Kouamé, L., P. (2014). Effect of cooking time on biochemical and functional properties of flours from Yam "kponan" (*Dioscorea cayenensis-rotundata*) Tubers. *British Journal of Applied Science & Technology*, 4(23): 3402-3418.
44. Aina, A. J., Falade, K. O., Akingbala, J. O., & Titus, P. (2012). Physicochemical Properties of Caribbean Sweet Potato (*Ipomoea batatas* (L) Lam) Starches. *Food Bioprocess Technol*, 5(2):576-83.
45. Nzewi, D., & Egbuonu, A. C. (2011). Effect of boiling and roasting on the proximate properties of asparagus bean (Vigna Sesquipedalis). *African Journal of Biotechnology*, *10*(54), 11239-11244.
46. Amani, N. G., Aboua, F., & Kamenan, A. (1991). Variation de la composition physico-chimique du taro (*Xanthosoma sagittifolium*) au cours de la transformation en farine. *Agronomie Africaine*, 3(1): 51-57.
47. Amani, N., Buléon, A., Kamenan, A., & Colonna, P. (2004). Variability in starch physicochemical and functional properties of yam (Dioscorea sp) cultivated in Ivory Coast. *Journal of the Science of Food and Agriculture*, *84*(15), 2085-2096.
48. Oyenuga, V. A. (1968). Nigeria's Foods and Feeding-stuffs. Their chemistry and nutritive value 3rd ed. *IUP. University of Ibadan, Ibadan, Nigeria*, 35-40.
49. Dadié, A., Aboua, F., & Coulibaly, S. (1998). Caractérisation physico-chimique de la farine et de l'amidon de la patate douce (*Ipomea batatas*). *Industrie AgroAlimentaire*, 36: 32-36.
50. Ayfer, M., Tu¨rk, R., & Eris, A. (1997). Chemical composition of Degˇirmendere hazelnut and its importance in human nutrition. *Acta Horticulturae*, 415, 51-53.
51. Bas, F., O'merogˇlu, S., Tu¨rdu¨, S., & Aktas, S. (1986). Onemli fındık c¸esitlerinin bilesim o¨zelliklerinin saptanması. *Gıda*, 11, 195-203.
52. Pala, M., Ac¸kurt, F., Löker, M., Yıldız, M., & Omerogˇlu, S. (1996). Fındık c¸esitlerinin bilesimi ve beslenme fizyolojisi bakımından degˇerlendirilmesi. *Turkish Journal of Agriculture and Forestry*, 20, 43-48.
53. Özdemir, F., Topuz, A., Dogan, U., & Karkacier, M. (1998). Some physical and chemical properties of hazelnut cultivars. *Gida*, 23(1): 37-41.
54. Larsson, S. C., & Wolk, A. (2007). Magnesium intake and risk of type 2 diabetes: a meta-analysis. *Journal of internal medicine*, *262*(2), 208-214.
55. Lee, S. H., Jouihan, H. A., Cooksey, R. C., Jones, D., Kim, H. J., Winge, D. R., & McClain, D. A. (2013). Manganese supplementation protects against diet-induced diabetes in wild type mice by enhancing insulin secretion. *Endocrinology*, *154*(3), 1029-1038.
56. Iheke, E., Oshodi, A., Omoboye, A., & Ogunlalu, O. (2017). Effect of Fermentation on the Physicochemical Properties and Nutritionally Valuable Minerals of Locust Bean (Parkia biglobosa). *American Journal of Food Technology*, *12*(6), 379-384.

57. Fennema, O., R. (1985). Food chemistry (2nd ed.). 270 Madıson Avenue, New York: Marcel Dekker, Inc., 991.
58. Saupi, N., Zakaria, M. H., & Bujang, J. S. (2009). Analytic chemical composition and mineral content of yellow velvetleaf (Limnocharis flava L. Buchenau)'s edible parts. *Journal of Applied Sciences*, *9*(16), 2969-2974.
59. FND. (2002). Dietary reference intake for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acid (micronutrients). FND, National Academy of Science USA.

