Journal of Agriculture and Crops
ISSN(e): 2412-6381, ISSN(p): 2413-886X
Vol. 9, Issue. 1, pp: 85-96, 2023
URL: https://arpgweb.com/journal/journal/14
DOI: https://doi.org/10.32861/jac.91.85.96

Academic Research Publishing Group

Original Research **Open Access**

Characterization of the Physicochemical, Functional, Granulometric and Mineral Properties of Néré (*Parkia Biglobosa*) FN, FW and FK Flours From Korhogo in Côte d'Ivoire

Niamke Arthur Michel (Corresponding Author)
Department of Biochemistry- Genetics, Biological Sciences Training and Research Unit, Peleforo Gon Coulibaly University, PO Box 1328, Korhogo, Côte d'Ivoire
Email: michel68niamke@gmail.com

Diarrassouba Gnoh Minata
Department of Biochemistry- Genetics, Biological Sciences Training and Research Unit, Peleforo Gon Coulibaly University, PO Box 1328, Korhogo, Côte d'Ivoire

Djaman Allico Joseph
Department of Biochemistry, Biosciences Training and Research Unit, Félix Houphouët-Boigny University, 22 PO Box 582, Abidjan, Côte d'Ivoire

Article History
Received: 29 August, 2022
Revised: 11 November, 2022
Accepted: 5 December, 2022
Published: 12 December, 2022

Abstract

The néré fruit is known in the north of Côte d'Ivoire for its seeds, which are used to prepare soumbara, and for its pulp, which is also consumed. Unfortunately, the nutritional value of the pulp is not known by the population and it is not processed by local industries. This study contributes to the valorization of néré fruits. After hulling, the pulp is dried in the sun, crushed, and sieved to produce three types of flour, depending on its origin. The flours from Niofoin, Waragniéré, and Kanoroba have been coded FN, FW, and FK respectively. The study of the physicochemical properties of the flours showed, depending on their origin, a moisture content of 5.4 to 7.6%, the average fibre content of 15.27%, high total carbohydrate content (81.05 to 84%), high energy value (360.4 to 369.13 Kcal/100g). The study showed the presence of antioxidants such as polyphenols (319.15 to 400.09mg/100g). Anti-nutrients like oxalates (7.42 to 10.81mg/100g) were found in low amounts. The study of functional properties showed a water absorption capacity of 199.54 to 207.55%, and an oil absorption capacity of 105.46 to 109.35%. The mineral study showed the presence of magnesium (0.05 to 0.076ppm), potassium (0.01 to 0.054ppm), calcium (0, 094 to 0.131ppm), iron (0.025ppm), copper (0.02 to 0.129ppm). The granulometric studies showed that the vast majority of the particles of the flours FN, FW, and FK, are smaller than 250 µm. The flours FN, FW, and FK contain macronutrients, high energy value, fibre, interesting functional properties, antioxidants, and minerals that are beneficial for the local populations and can be used by the food industries.

Keywords: Flour; *Parkia biglobosa*; Physicochemical properties; Functional properties; Minerals; Particle size.

How to Cite: Niamke Arthur Michel, Diarrassouba Gnoh Minata, Djaman Allico Joseph, 2022. "Characterization of the Physicochemical, Functional, Granulometric and Mineral Properties of Néré (*Parkia Biglobosa*) FN, FW and FK Flours From Korhogo in Côte d'Ivoire." *Journal of Agriculture and Crops*, vol. 9, pp. 85-96.

1. Introduction

Human beings depend heavily on natural resources for their survival. Wild fruits play an important role in the diet of people, especially in rural areas. These wild fruits from plants such as néré, baobab, shea, tamarind etc. constitute one of the main sources of monetary income and contribute to improving the quality of the food ration through the provision of nutrients [1]. Parkia biglobosa, commonly known as néré, is a woody food species of multiple-use tree parks belonging to the genus Parkia and the legume family whose importance is well recognised both regionally [2]. The pod-shaped fruits of P. biglobosa are consumed not only for their sweet, floury pulp but also and especially for their seeds used in the preparation of fermented condiments in West Africa. The néré is a distinctive tree of the Guinean and Sudanian zones of West Africa, with a lifespan of up to 100 years [3]. The néré is one of the most important products of the Non-Timber Forest Products (NTFPs). It is part of the diet and nutritional balance of households, contributes to the improvement of the health of the inhabitants, and provides employment and income to rural households. Its development will undoubtedly contribute to improving household food security, particularly in rural areas [4, 5].

Because of its importance as a food source and its many uses in traditional African pharmacopoeia, the néré tree is one of the most respected trees in the agricultural production system in many African countries. It is conserved and protected in tree parks in association with other useful trees [6]. The seeds of néré are widely consumed and traded regionally by local communities in its West African range [7]. The seed is used to make soumbara, which is a widely used condiment throughout Sudanian Africa, and the pulp is an emergency food for rural people at the end of the dry season when crops are often largely exhausted [8]. However, pulp is an important local food for the local population. It is consumed in the form of porridge. In Côte d'Ivoire, néré is growing in the northern savannahs [9].

The néré is well known for its numerous anti-blennorrhagic, antineuralgic, diuretic, febrifuge, tonic, antiseptic and vermifuge properties. Its fat-rich seeds are used to make a vegetable cheese to season sauces (Soumbara), or as a coffee substitute" [9]. The barks and roots of this plant are prescribed to treat sterility, venereal diseases, bronchitis, hepatitis and leprosy. The leaves in steam baths are used to treat febrile states and intestinal parasitosis" [9].

Nevertheless, the nutritional value of néré flour is unknown to the population in the department of Korhogo, in localities such as Niofoin, Waragnéré, Kanoroba, despite the presence of many trees, and it is little used in industry

Current study is attempted to provide data regarding the physicochemical, functional, granulometric, antioxidant, minerals properties of néré flours (FN, FW, FK) and thus to contribute in the valorization of néré (*Parkia biglobosa*).

2. Material and Methods

2.1. Biological Material

The biological material used was essentially made up of néré (*Parkia biglobosa*) pods collected in April 2022, in three (3) large areas (Kanoroba, Niofoin and Waragnéré), in the department of Korhogo, in the north of Côte d'Ivoire, which have a significant néré stand.

2.2. Methods

2.2.1. Sampling

For each zone (Kanoroba, Niofoin and Waragnéré), 20 kg of néré pod samples were collected from three (3) different locations, making 60 kg of pods per zone. For each zone, the samples were put together in 100kg bags and transported to Korhogo for flour production.

2.2.2. Production of néré flour

The néré flour was obtained through different steps:

The néré pods were sorted and dehulled by area. After hulling, the yellow pulp containing seeds was obtained. It was sorted and then stored in a bag before drying. For each zone, the yellow pulp obtained, containing the seeds, was dried for two (2) days in the sun. The dried yellow pulp was crushed on the third day, by zone, in a mortar with a hand pestle to obtain the seed and the yellow néré flour separately. The sieving was done with a 2mm diameter sieve, by zone, to separate the flour from the seed. Thus three flours were obtained according to their origin. Flour from Niofoin, Waragnéré and Kanoroba were coded FN, FW and FK respectively. The flour obtained was then weighed with a scale to determine the number of kilograms obtained for each zone and finally the flour was stored in plastic buckets.

2.2.3. Yield of Nere Flour

The flour yield for each zone was obtained by dividing the mass of flour obtained after drying by the total mass of néré fruits harvested per zone (60 kg). The result was multiplied by 100.

2.2.4. Determination of Physico-Chemical Properties

2.2.4.1. Moisture Content

The method of moisture determination is that proposed by AOAC [10]. Moisture was assessed by drying 5 g of FN, FW, FK flours in an oven (MEMMERT) at 105 °C for 24 h.

2.2.4.2. Ash Content

The ash content (total mineral matter) was determined according to the method described by AOAC [10] by incinerating five (5) grams of each flour in a muffle furnace (PYROLABO) at 550°C for 12 h.

2.2.4.3. Determination of pH

The pH was determined according to the AOAC [10] method. Ten (10) grams of sample were diluted in 100 mL of distilled water for 1H. The solution obtained was filtered through filter paper (Whatman). The pH was measured directly by immersing the electrode of the pH meter (HANNA), previously calibrated, in the filtrate obtained.

2.2.4.4. Total and Reducing Sugar Content

2.2.4.4.1. Extraction of Ethanosoluble Sugars

Ethanosoluble sugars were extracted according to the method of Agbo, *et al.* [11] as follows.

One (1) gram of flour was weighed and then diluted in 10 mL of ethanol (80%; v/v). To the resulting mixture were added 2 mL of zinc acetate (10%; w/v) and 2 mL of oxalic acid (10%, w/v). The mixture was then centrifuged at 3000 rpm for 10 min. The pellet was taken up with 10 mL ethanol (80%; v/v) and centrifuged again at 3000 rpm for 10 min. The supernatants were transferred to a 50 mL flask and the excess ethanol was evaporated in a sand bath for 10 min. The resulting solution was made up to 50 mL with distilled water.

2.2.4.4.2. Determination of Total Sugars

The total sugar content was determined according to the phenol-sulphuric method as described by Dubois, *et al.* [12].

One hundred (100) µL of ethanosoluble sugar extract was introduced into a test tube, then 0.9 mL of distilled water, 1 mL of 5% (w/v) phenol and 5 mL of concentrated sulphuric acid are added successively. After shaking and cooling the tube, the absorbance was read with a spectrophotometer (PG INSTRUMENTS) at 490 nm against a blank. The determination of the quantity of total sugars was carried out using a standard range of glucose stock solution at 1 mg/mL carried out under the same conditions as the test.

2.2.4.4.3. Determination of Reducing Sugars

The quantification of reducing sugars was performed according to the method of Bernfeld [13]**.**

One (1) mL of ethanosoluble extract of sugars was introduced into a test tube. To the contents of this tube, 0.5 mL of distilled water and 0.5 mL of DNS solution were added. The whole mixture was heated in a boiling water bath for 5 min. After cooling, 2 mL of distilled water was added and the absorbance of the solution was read with a spectrophotometer (PG INSTRUMENTS) at 540 nm against a blank. A standard range established under the same conditions as the test from a stock solution of glucose (1 mg/mL) was used to determine the quantity of reducing sugars.

2.2.4.5. Lipid Content

Lipids were quantified from 10 g of each flour by Soxhlet extraction using 300 mL n-hexane for 7 h [14]. The resulting hexane-oil mixture was recovered and separated with a rotavapor (Heidolph). The flask, initially tared and containing the oil, was weighed to determine the mass of oil extracted.

2.2.4.6. Protein Content

Crude protein was determined by total nitrogen determination according to the Kjeldhal method AOAC [10]. Thus 1g of each flour was mineralised in the presence of Kjeldahl catalysts (potassium sulphate K_2SO_4 and copper sulphate and concentrated sulphuric acid H_2SO_4). The mineralisate was purified by distillation. Nitrogen was then quantified by titration with 0.1 N H_2SO_4. The crude protein content of the flours was deduced from the nitrogen content using 6.25 as a conversion factor.

2.2.4.7. Fibers Content

The determination of the fibers content was carried out according to the method of Wolff [15]**.** The determination of the crude fibers content consisted in treatment of 2 g of FN, FW, FK flours sample with 50 mL of 0.25 N sulfuric acid and 50 mL of 0.31 N sodium hydroxide and filtration of the resulting solution upon Whatman paper. The residue was dried for 8 h at 105 °C then incinerated at 550 °C for 3 h into ovens. The final residue was weighed as crude fibers and expressed in percentage.

2.2.4.8. Total Carbohydrates Content and Energy Value

Total carbohydrates and energy values were determined using calculation formulas recommended by FAO [16] accounting the moisture, fat, protein, ash contents and the energy coefficients for macromolecules.

TCC (%) = 100-[P(%) + M(%) + F(%)+A(%)] CEV (kcal/100g) = [(4×P) + (9×F) + (4×C)] With: TCC, total carbohydrates content; CEV, caloric energy value; P, protein content; M, moisture content; F, fat content; A, ash content; C, total carbohydrates content

2.2.4.9. Oxalates Content

The oxalate content was determined with the standard AOAC method AOAC [10]. Two (2) grams of FN, FW, FK flour sample were homogenised into 200 mL of distilled water and added with 20 mL of 6N hydrochloric acid (HCl). The mixture was heated in boiling water bath for 1 h, cooled, and filtered. Fifty (50) mL of the filtrate were then homogenised into 20 mL of 6 N HCl, and filtered again. The 2nd filtrate was treated with methyl red (0.1%, w/v), concentrated ammonia, heated, and filtered. The 3rd filtrate was boiled, treated with calcium chloride (5%, w/v) for the formation of calcium oxalate crystals, and then filtered once more. The residues deriving from the filtration steps were successively washed with distilled boiling water, dried into an oven; dissolved into 10 mL of diluted sulfuric acid, and titrated with 0.05N potassium permanganate solution.

2.2.4.10. Phytates Content

The phytates were measured according to the method processed by Mohammed, *et al.* [17]. A slight flour sample (0.5 g) was treated with 25 mL of TCA solution at 3% (w/v) and centrifuged at 3,500 rpm for 15 min. Five (5) mL of the supernatant was removed, treated with 3 mL of ferric chloride 1% (w/v) reagent, heated in a boiling water bath, cooled and also centrifuged at 3,500 rpm for 10 min. The 2nd supernatant was treated with 5 mL of 0.5N hydrochloric acid, 5 mL of 1.5N sodium hydroxide, heated in a boiling water bath and centrifuged once more at 3500 rpm for 10 min. Thus, 1 mL of the final supernatant was added with 4.5 mL of distilled water and 4.5 mL of orthophenantroline reagent and then measured for the absorbance at 470 nm with a spectrophotometer against standard Mohr salt solution treated likewise and taken as phytates ferric control.

2.2.5. Determination of Antioxidants

2.2.5.1. Extraction of Phenolic Compounds

Phenolic compounds were extracted with methanol by the method of Singleton, *et al.* [18].

One (1) gram of sample of FN, FW, FK flours was homogenised in 10mL of 70% (v/v) methanol. The resulting mixture was centrifuged at 1000 rpm for 10 min. The pellet was recovered in 10 mL of 70% (v/v) methanol and centrifuged again. The supernatants were collected in a 50 mL flask and made up to the mark with distilled water.

2.2.5.2. Determination of Total Phenols

The method of Singleton, *et al.* [18] was used for the determination of total phenols. One (1) mL of methanolic extract was introduced into a test tube. To the contents of the tube is added 1mL of Folin-ciocalteu reagent. The tube was left to stand for 3min and then 1mL of 20% (w/v) sodium carbonate solution was added. The contents of the tube were made up to 10 mL with distilled water. The tube was placed in the dark for 30 min and the OD reading is taken at 745 nm against a blank. The amount of phenol in the sample was determined by a standard range using a stock solution of gallic acid (1 mg/mL) under the same conditions as the test.

2.2.5.3. Determination of Tannins

The determination of tannins was carried out according to the method described by Bainbridge, *et al.* [19]. One (1) mL of methanolic extract was introduced into a test tube. To the contents of the tube were added 5 mL of vanillin reagent. The tube was left to stand for 20 min in the dark and the optical density (OD) was read at 500 nm against a blank. The amount of tannin in the samples was determined using a standard solution of tannic acid (2 mg/mL) under the same conditions as the test.

2.2.5.4. Determination of Flavonoids

The flavonoid assay was performed as described by Meda, *et al.* [20].

A volume of 0.5 mL of methanolic extract was introduced into a test tube. To the contents of the tube were successively added 0.5 mL of distilled water, 0.5 mL of 10% aluminium chloride, 0.5 mL of 1M potassium acetate and 2 mL of distilled water. The tube was allowed to stand for 20 min in the dark and the optical density (OD) was read at 415 nm against a blank. The amount of flavonoids in the sample was determined using a standard solution of quercetin (0.1 mg/mL) under the same conditions as the test.

2.2.6. Determination of Functional Properties

2.2.6.1. Tapped Density

The tapped density (DT) of the flours was determined using the (modified) technique of Oadele and Aina [21]. A quantity of 50 g of flour (ME) was placed in a 100 mL graduated cylinder. The test tube was then gently tapped on the bench until a constant volume Vt.

2.2.6.2. Water Absorption capacity (WAC) and Water Solubility Index (WSI)

The water absorption capacity (WAC) and water solubility index (WSI) of the flours were determined according to the (modified) techniques of Phillips, *et al.* [22] and Anderson, *et al.* [23] respectively. Exactly 1 g of each flour (M0) was dissolved in 10 mL of distilled water in a centrifuge tube. This mixture was stirred for 30 min by a shaker and then kept in a water bath at 37 °C for 30 min. It was then centrifuged at 14674 xg for 15 min in an ORTO ALRESAR centrifuge. The resulting pellet (M2) was weighed and then dried at 105 °C to a constant mass (M1). The WAC and WSI were calculated from the following relationships:

$$WAC\ (\%) = \frac{(M_2 - M_1)}{M_1} \times 100$$

$$WSI\ (\%) = \frac{(M_0 - M_1)}{M_0} \times 100$$

$$DT\ (g/ml) = \frac{ME}{Vt}$$

2.2.6.3. Oil Absorption Capacity

The oil absorption capacity of the flours was determined using the (modified) technique of Eke and Okobundu [24]. A 1 g sample (M0) of flour was dissolved in 10 mL of oil. The mixture was stirred for 30 min at room temperature using a magnetic stirrer and then centrifuged at 11886 xg for 10 min in an ORTO ALRESAR centrifuge. The recovered pellet was weighed (M1). The oil absorption capacity (OAC) was calculated from the following formula:

$$OAC\ (\%) = \frac{(M_1 - M_0)}{M_0} \times 100$$

2.2.7. Determination of Flour Grain Size

The particle size of the flours was estimated by fractionating the total mass of flours through a series of sieves of decreasing mesh size (2mm, 1mm, 500um, 250um, 125um and 63um). Underneath the 63um sieve was a collection lid.

The sample was placed in a sieve with different mesh sizes and closed with a lid. The sieve was stirred for 30 minutesThe grains are deposited one after the other according to their diameter size and the rejects and passings of each sieve were weighed with a technical balance (Denver instrument SI-4002) of precision.

2.2.8. Determination of Minérals

The determination of the minerals was carried out by atomic absorption with an air-acetylene flame AAS 20 type VARIAN.

The FN, FW, FK flours were ground to a particle size of 0.1mm. A mass of 0.3 g of each flour was calcined at 600°C for 5h in an oven until a white ash is obtained. After cooling, 5 mL of 1N nitric acid was added and evaporated to dryness on a sand bath. To the residue was added 5mL of 1N hydrochloric acid and the whole was fired again at 400°C for 30 min. Once the calcined product was recovered from the furnace, 10mL of 0.1N hydrochloric acid was added to the crucible to recover the product. The resulting mixture was poured directly into a 50 ml volumetric flask. The operation (washing the crucible with 10 ml of 0.1 ml HCL) was repeated three times and the flask is filled to the mark. Allow to decant and take the supernatant for filtration with 0.45 µm wattman paper or with a 0.36 syringe filter. The elements contained in the solution were then determined by AAS.

NB: To avoid interference from the elements Ca, K, 5 ml of lantane chloride was added.

2.2.9. Statistical Studies

All analyses were performed in triplicate and the data processed using the Statistical Program for Social Sciences (SPSS version 20.0, SPSS for Windows, USA). For each characteristic, the results were expressed as means followed by their standard deviations as data dispersion parameters. A one-way analysis of variance (ANOVA 1) was also performed to test the effect of flour on the characteristics evaluated, at the 5% statistical significance level. For statistically different means, classification was performed with the Student-Newman-Keuls test.

3. Results

3.1. Physico-Chemical Properties (Table 1)

Flour yields were statistically different from one locality to another at the 5% threshold. FN flour had the highest yield (9.17%) while FK flour had the lowest yield (7.5%). The quantity of flour in a pod was therefore low. For moisture, FN and FW flours had statistically identical and lower contents. On the other hand, FK flour had the highest moisture content (7.6%). The highest ash content was found in the FN flour (4.97%), while the lowest content was found in the FW and FK flours, which did not differ statistically at the 5% level. With regard to pH, there was no significant difference between the values of the three flours, giving an average pH of 5.27. The FW flour had the highest reducing sugar content (17.84 mg/100g) and the FN flour the lowest reducing sugar content (14.88 mg/100g). FN and FK flours had statistically identical and minimal total sugar contents. On the other hand, the FW flour had the highest total sugar content (54.54%). For lipids, the highest content was found in FW flour (2.31%) and the lowest in FN flour (1.5%). The lowest protein content was found in the FN flour (4.12%). In contrast, FK flour had the highest protein content (5.06%). The three flours FN, FW, FK did not differ significantly in fibre content at the 5% level, giving an average value of 15.27%. The total carbohydrate content of the FN flour was the highest (84.003%). Conversely, FK flour had the lowest content (81.05%). FK flour had the lowest energy value (360.47 Kcal/100g); FW flour had the highest energy value (369.13 Kcal/100g).

Table-1. Physico-chemical properties

Parameters	FN	FW	FK	General average	P-value
Colour	Yellow	Yellow	yellow		-
Flour yields (%)	9.17±0.08c	8.33±0.13b	7.5±0.53a		0.002
Moisture (%)	5.4±0.36a	6.4±0.87a	7.6±0.63b		0.014
Ashes (%)	4.97±0.1b	4.21±0.18a	4.51±0.24a		0.006
pH	5.32±0.04a	5.24±0.05a	5.24±0.04a	5.27	0.113
Reducing sugar (mg/100g)	14.88±0.04a	17.84±0.49c	15.84±0.18b		0.000
Total sugar (%)	51.06±0.43a	54.54±0.44b	51.54±0.45a		0.002
Lipids (%)	1.5±0.2a	2.31±0.07c	1.78±0.04b		0.001
Proteins (%)	4.12±0.01a	4.28±0.05b	5.06±0.01c		0.000
Fibres (%)	15.62±0.54a	15.35±0.27a	14.83±0.29a	15.27	0.114
Total carbohydrate (%)	84.003± 0.33c	82.80 ±0.69b	81.05±0.38a		0.001
Energy value (Kcal/100g)	366.03±1.66b	369.13± 3.04c	360.4 ± 1.69a		0.009

Per line, values followed by different letters are statistically different at 5%. P-value: value of the statistical probability test. With a < b<c; P value < 0.05 (5%) so the difference is significant

3.2. Antioxidants and Anti-Nutrients (Table 2)

Statistical analysis showed that the polyphenol content of the three flours FN, FK, FW was different at the 5% threshold. FK flour had the highest content (400.09 mg/100g) while FN flour had the lowest content (319.15 mg/100g). The flavonoid content was lowest in the FN flour (91.07 mg/100g) and highest in the FW flour (127.75 mg/100g). The lowest tannin content was identified in FN flour (77.67 mg/100g) and the highest in FK flour (99.45 mg/100g).

As for oxalates, FW flour had the highest content (10.81 mg/100g) while FK flour had the lowest content (7.42 mg/100g). On the other hand, FK flour had the highest phytate content (19.62 mg/100g). The lowest content was presented by the FN flour (15,03mg/100g).

Table-2. Antioxidants et anti-nutrients

Parameters		FN	FW	FK	P-value
Antioxidants	**Polyphenols (mg/100g)**	319.15±0.65a	386.84±0.3b	400.09±1,11c	0.000
	Flavonoids (mg/100g)	91.07±0.72a	103.34±0.55b	127.75±0.06c	0.000
	Tannins (mg/100g)	77.67±0.5a	87.81±0.86b	99.45±0.57c	0.000
Anti-nutrients	**Oxalates (mg/100g)**	8.31±0.21b	10.81±0.77c	7.42±0.53a	0.001
	Phytates (mg/100g)	15.03±0.53a	16.20±0.11b	19.62±0.51c	0.000

Per line, values followed by different letters are statistically different at 5%. P-value: value of the statistical probability test. With a < b<c; P value < 0.05 (5%) so the difference is significant.

3.3. Functional Properties (Table 3)

For tapped density, FN and FW flours had the highest values that were not significantly different at the 5% threshold. Conversely, FK flour had the lowest value (0.32g/ml). FN flour had the lowest water absorption capacity (199.54%); and FK flour had the highest content (207.55%). In terms of water solubility index, FN flour had the highest content (63.94%) while FK flour had the lowest content (38.88%). As for the oil absorption capacity, FW and FK flours had the highest values, which were statistically not different at the 5% threshold. On the other hand, FN flour had the lowest oil absorption capacity (105.46%).

Table-3. Functional properties

Parameters	FN	FW	FK	P-value
Tapped density (g/ml)	0.42 ± 0.04b	0.39 ± 0.025b	0.32 ± 0.03a	0.028
Water absorption capacity (%)	199.54 ± 0.04a	204.63 ± 0.02b	207.55 ± 0.07c	0.000
Water solubility index (%)	63.94 ± 0.04c	44.92 ± 0.03b	38.88 ± 0,03a	0.000
Oil absorption capacity (%)	105.46 ± 0.58a	109.35 ± 0.05b	109.21 ± 0.08b	0.000

Per line, values followed by different letters are statistically different at 5%. P-value: value of the statistical probability test. With a < b<c; P value < 0.05 (5%) so the difference is significant.

3.4. Minerals (Table 4)

Statistical studies showed a significant difference between the values of FN, FW, FK flours for magnesium. Thus, FN flour had the lowest content (0.05 ppm) while FW flour had the highest value (0.076 pm). The statistical studies did not show any significant difference at the 5% level between the phosphorus contents of the three flours FN, FW, FK, with an average content of 0.028 ppm. As for potassium, the FK flour had the highest content (0.054

ppm) while the FW flour had the lowest content (0.01 ppm). Calcium content was highest in FK flour (0.131 ppm) and lowest in FN flour (0.094 ppm). The FN, FW and FK flours did not show any significant difference at the 5% threshold for their manganese content, with an average of 0.045 ppm. The same results were observed for iron, nickel and molybdenum with respective averages of 0.025 ppm, 0.026 ppm and 0.025 ppm. For copper, the highest content was observed in the FW flour (0.129 ppm) and the lowest in the FK flour (0.02).

Table-4. Minerals

Parameters	FN	FW	FK	General average	P-value
Magnesium (ppm)	0.050±0.004a	0.076±0.006c	0.066±0.004b		0.001
Phosphorus (ppm)	0.030±0.003a	0.024±0.005a	0.031±0.003a	0.028	0.121
Potassium (ppm)	0.034±0.004b	0.010±0.002a	0.054±0.004c		0.000
Calcium (ppm)	0.094±0.006a	0.109±0.004b	0.131±0.009c		0.001
Manganese (ppm)	0.042±0.003a	0.047±0.004a	0.046±0.008a	0.045	0.508
Iron (ppm)	0.027±0.003a	0.025±0.006a	0.024±0.004a	0.025	0.714
Nickel (ppm)	0.026±0.004a	0.027±0.005a	0.026±0.007a	0.026	0.968
Copper (ppm)	0.109±0.01b	0.129±0.005c	0.020±0.004a		0.000
Molybdenum (ppm)	0.027±0.001a	0.027±0.007a	0.022±0.004a	0.025	0.367

Per line, values followed by different letters are statistically different at 5%. P-value: value of the statistical probability test. With a < b<c; P value < 0.05 (5%) so the difference is significant.

3.5. Determination of Particle Size (Table 5)

The results of the particle size analysis of FN, FW, FK flours were presented in Table 5. These results showed that the vast majority of the particles of the flours FN, FW, FK (76.7% for FN; 83.5% for FW; 79.2% for FK), were smaller than 250 µm and almost all the particles of the three flours (100% for FN, 99.2% for FW, 97.1% for FK) were larger than 125 µm.

Table-5. Size distribution (% passing the sieve) of FN, FW, FK flours

	Maille des tamis					
Farines	**<2mm**	**<1mm**	**<500µm**	**<250µm**	**<125µm**	**<63µm**
FN	**100**	**99.3**	**86.7**	**76.7**	**0**	**0**
FW	**100**	**99.4**	**91.1**	**83.5**	**0.8**	**0**
FK	**100**	**99.79**	**88.4**	**79.2**	**2.9**	**0**

4. Discussion

4.1. Physico-chemical properties

The flour yields were 9.17%; 8.33%; 7.5% for FN, FW, FK flours respectively. The quantity of flour in a fruit is therefore low. The pod and the seeds together represented almost the entire weight of the fruit.

The moisture content of néré flour varied from 5.4% to 7.6% depending on the locality. It was lower than the moisture content of FT couscous flour (11.22%), which was composed of maize and sorghum [25]. These moisture levels were below the maximum level of 15.5% defined by the Codex Alimentarius Commission [26]. Indeed, when the moisture content is high, aggregation of the flour particles occurs, reducing its quality and functionality [27]. Another advantage of having a low moisture content lies in the technological uses. With a moisture content of less than 12%, both untreated and treated flours are suitable for long-term storage. Microbiologically, these low moisture levels limit the growth of microorganisms, with the exception of moulds [28].

The pH of néré flour was slightly acidic, ranging from 5.24 to 5.32. This pH was lower than that of F1 Yellow Nutsedge (*Cyperus esculentus*) flour which was 6.14 according to Yapi, *et al.* [29]. The pH is a sign of the acidity or alkalinity of the flour and greatly affects its performance during its use in the food system. When a flour has a pH lower than 4, it is said to be very acidic, indicating a high degree of fermentation and consequently a high degree of degradation of the starch present, which would make this type of flour unsuitable for bread making [30].

The analysis of physicochemical properties showed that néré flour had a total sugar content that varied from 51.06% to 54.54% and a reducing sugar content that varied from 14.88 mg/100g to 17.84 mg/100g. These levels were higher than those observed by Gutap and Nagar [31] for total sugars; but these values were lower for reducing sugars. These authors obtained total sugar levels between 0.05 and 0.4% in uncooked and cooked soybean flours and also reducing sugar levels between 0.03 and 0.04%. Néré flour is sweet. It should be noted that flours rich in sugars are useful for the manufacture of certain foods such as cakes, biscuits and cakes.

The lipid contents of néré flour varied from 1.5 to 2.31%. These contents were higher than those obtained by Oulaï [32] (0.84% to 0.48%) during the cooking of *Artocarpus altilis* pulp. According to Anses [33], lipids play two (2) major roles: an energy storage role and a structural role (enter in the composition of cells).

The percentage of protein in néré flour (4.12 to 5.06%) was lower than that of FS, F40, F50 flours (6.23 to 7.57%) of young shoots of roan [34]. Proteins are essential to the organism, they play a structural role (at muscle

level, skin pathway) but are also involved in a large number of processes such as immune response (antibodies), oxygen transport in the body (haemoglobin) or digestion (digestive enzymes) [33].

The total fibre content of néré flour (14.83 to 15.35%) was higher than that of washed and dried soybean flour (FSLS) (5.20%) highlighted by Djidohokpin [35]. This flour could be a significant source of dietary fibre which is eliminated more slowly from the stomach and thus improves intestinal transit. These dietary fibres are absolutely essential for the balance of the digestive tract and the body. It is a factor in good health. Studies have shown an inverse correlation between dietary fibre consumption and colon cancer. This is because fibre has the ability to complex with carcinogenic molecules, thus preventing their contact with the colon and facilitating their excretion [36]. Consumption of prepared flours could therefore increase gastric volume and provide a post-ingestive state to reach a state of satiety more quickly [37]. Fibre generally reduces blood glucose, HDL-cholesterol, LDL-cholesterol and thus contributes to the reduction of coronary heart disease [38].

The percentage of total carbohydrates in néré flour (81.05 to 84%) was close to that of fonio flour (Namba variety) (87.49%) [35]. Néré flour is therefore an important source of carbohydrate. It constitutes an energy reserve that can be used during glycolysis by forming ATP molecules. The high percentage of carbohydrate in cowpea flour makes it an energy food that can contribute to food security in developing countries [39].

The energy value of néré flour (360.47-369.13Kcal/100g) was higher than that reported by Cruz, *et al.* [40] which was 350Kcal/100g for fonio. Néré flour could be used in part as energy flour in porridges for infants and children whose energy needs vary from 547 to 1092 Kcal/day [41].

4.2. Antioxidants et anti-nutrients

The content of polyphenols (319.15 to 400.09 mg/100g), flavonoids (91.07 to 127.75 mg/100g) and tannins (77.67 to 99.45 mg/100g) in néré flour was higher than in FS, F40, F50 flours in polyphenols (243.45 to 280.44 mg/100g), flavonoids (68.46 to 83.03 mg/100g), tannins (45.47 to 59 mg/100g) [34].

The presence of antioxidants may reflect a response to stress (scarcity of rainfall, unfavourable soil quality which are associated with an increase in tannin levels) [42]. Thus, depending on the efforts made to adapt to the environmental conditions of the plant, the amount of antioxidant increases or decreases.

Flavonoids can neutralise free radicals and reduce cancer risk by stopping cell growth in tumours [43].

Current literature suggests that long-term consumption of a polyphenol-rich diet protects against certain cancers, cardiovascular disease, type 2 diabetes, osteoporosis, pancreatitis, gastrointestinal problems, lung damage and neurodegenerative diseases [44].

Anti-nutrients such as oxalates and phytates were present in néré flour. The oxalate content (7.42 to 8.31 mg/100g) was lower than that of flour from the uncooked pulp of Artocarpus altilis fruit (66.84 mg/100g) [32], High levels of oxalates in the diet can lead to stomach and kidney irritation (kidney stone formation) [45].

The phytate content of néré flour (15.03 to 19.62 mg/100g) was lower than that of flour from the uncooked pulp of the fruit of Artocarpus altilis (63.4 mg/100g) **[32].** Phytates have multiple negative charges, which gives them a strong binding capacity, resulting in the formation of complexes with proteins and multivalent cations (Cu2+, Zn2+, Fe2+...) thus decreasing their biodiponibility [46].

4.3. Functional Properties

The tapped density (0.32 to 0.42 g/ml) of néré flour was lower than those of maize (0.60 g/cm3) and wheat (0.62 g/cm3) flours found by FAO [47]. It is very important for packaging requirements in the food industry [48]. The tapped density determines the suitability of a flour to be easily packaged, which would facilitate the transportation of a large amount of food [49]. Thus, the low packing density of cowpea flour is thought to be due to the size of the particles. The smaller the particles, the more easily they aggregate. Nutritionally, a low tapped density promotes the digestibility of food products, especially in children because of their immature digestive system [50].

Water absorption capacity (WAC) is an index of the maximum amount of water a food product would absorb and hold [51]. Néré flour showed a WAC between 199.54 and 207.55%. These values were lower than those of uncooked (225%) and cooked (250%) rice reported by Abulude [52]. Furthermore, the use of flours as food ingredients depends, to a large extent, on their interaction with water. The water absorption capacity of flours plays an important role in the food preparation process as it predicts the ability of the flour to absorb water under conditions where water is in short supply. A high capacity allows more water to be added to the dough, thus improving its workability. Furthermore, water absorption capacity is an essential property of doughs and baked goods as it allows for thickening and increasing the viscosity of foods [53]. The high water absorption capacity of néré flour may reflect the presence of high amounts of hydrophilic substances capable of improving the viscosity of various food products [54]. This could also reflect a greater interaction between the proteins and water in the system formed. Furthermore, the type of protein such as polar proteins would also increase this ability [30, 54].

The water solubility index (WSI) (38.86 to 63.9%) was higher than that of the uncooked Artocarpus altilis pulp flour (33.37%) [32]. The water solubility index, reflects the extent of starch grain degradation in the flour [55].

The oil absorption capacity (105.46-109.35%) was much lower than those of edible mushroom flours which are between 450-480% [56]. Oil absorption capacity (OAC) is an important property in food preservation as it prevents the development of oxidative rancidity [57]. Oil absorption capacity gives an indication of the flavour retention capacity of flour [58]. Moreover, it is useful over a long period of food preservation especially in bakery and meat products [59]. Since this flour has a high oil absorption capacity, it could be a good lipophilic component and therefore suitable for the preparation of sausages, soups and cakes [56].

4.4. Mineral Determination

The magnesium content of néré flour (0.05-0.076mg/kg) was lower than that of peanuts (1350ppm) [60]. The potassium content of néré flour (0.01-0.054mg/kg) was lower than that of white beans (16600ppm) [61] Potassium is a mineral that increases cardiovascular well-being as is magnesium, which is recommended for the prevention of certain complications of myocardial infarction [62, 63].

The phosphorus content (0.024 to 0.031mg/kg) of néré flour was lower than that of brown rice (2350ppm) [64] The calcium content of néré flour (0.094 to 0.131mg/kg) was lower than that of groundnuts (550 ppm) [65]. A diet rich in calcium and phosphorus is a factor in the prevention of osteoporosis and also a factor in reducing the risk of high blood pressure, colon and prostate cancer [66].

The iron content of néré flour (0.024-0.027 mg/kg) was lower than that of sweet potato flour (10.97 ppm) revealed by Ofori, *et al.* [67]. The iron values of néré flour is below the limit of 15 mg/Kg set by WHO as the limit of iron in food [68]. Iron plays an important role in the human body. The haemoglobin in the red blood cells absorbs the 70% of iron consumed. This allows oxygen to function properly. This oxygen is then transmitted to the cells. Iron is also found in the myoglobin of the muscles, which enables air to be stored. The remaining 30% of iron plays a role in activating the body's metabolisms. It contributes greatly to the production of energy and the activation of the immune system [69]. Iron deficiency anaemia affects one third of the world's population. However, excessive iron intake causes colorectal cancer [70].

The nickel content of néré flour (0.026 to 0.027mg/kg) was lower than that of desiccated coconut (1.36 ppm) (https://biorganic.blog/2018/05/05/2-528-aliment-riches-en-nickel-ni/ accessed on 29/05/2022). The content of néré flour was lower than the limit set by [71] (1.63 ppm). Nickel is a trace element and is involved in the assimilation and metabolism of iron. It appears to be essential for the action of several enzymes (https://www.doctissimo.fr/html/nutrition/vitamines_mineraux/nickel.htm accessed on 18/05/2022).

The copper content of néré flour (0.020 to 0.129 mg/kg) was lower than that of taro flour (6.63 ppm) revealed by Ofori, *et al.* [67]. Well below the WHO limit of 40 ppm for copper in food [68]**.** Copper is an "essential trace element for body function. It is a powerful antioxidant, which helps to combat cellular stress in the event of problems of excess oxidation. It allows the assimilation of iron, which itself allows the production of red blood cells. It contributes to the formation of the immune system. It plays a role in glucose metabolism. It plays a role in the regulation of neurotransmitters, as it is a cofactor in the synthesis of noradrenaline. It thus contributes to the normal functioning of the nervous system. It is involved in the synthesis of melanin and thus provides a better defence against UV radiation [72].

The molybdenum content of néré flour (0.022-0.027 mg/kg) was lower than that of beans (0.5 mg/kg) [73]. Molybdenum is an essential trace element for the body. It is used in the composition of metalloenzymes that function as oxidases by virtue of the characteristics of its redox couples. The 3 best known Mo-dependent enzymes are: xanthine oxidase/deshydrogenase (XO/XD, transformation of purines into uric acid), aldehyde oxidase (oxidation of aldehydes) and sulphite oxidase (oxidation of sulphite into sulphate in the metabolism of sulphur-containing amino acids). It takes part in the constitution of the "Mo cofactor" or "molybdopterin" in the liver. Although not regulated by Mo intake, deficiency of this cofactor is the cause of a rare genetic disease affecting young children and causing their death as a result of severe neurological disorders. The element is involved in biological functions related to the metabolism of purines (accumulation of xanthine in case of deficiency or uric acid in case of excess), sulphites (detoxification by oxidation), sulphates (formation of sulphated body constituents) or iron (incorporation on transferrin by Xanthine Oxidase) [74].

The manganese content of néré flour (0.042-0.046 mg/kg) was lower than that of cooked brown rice (11mg/kg) [75]. Manganese is involved in the constitution of several metalloenzymes including superoxide dismutase (MnSOD, antioxidant), arginase (conversion of arginine to ornithine and urea) or pyruvate carboxylase (carboxylation of pyruvate in gluconeogenesis**)** [76] The element participates in several biological functions relating to the constitution of the skeleton and cartilage, lipid metabolism, regulation of glycaemia or even cerebral and nervous activity. Finally, its antioxidant role is important in the mitochondria [76].

4.5. The Grain Size of FN, FW, FK Flours

The vast majority of the particles of FN, FW, FK flours were smaller than 250 µm and almost all the particles of the three flours are larger than 125 µm. The granulometry of the flours is of major importance for their analysis and use. Indeed, it makes it possible to detect the presence of foreign particles and to pronounce on milling problems. It plays a fundamental role in hydration during the bread-making process and the preparation of the dough. It also makes it possible to predict its behaviour during hydration. In baking, the amount of water absorbed during dough fermentation, as well as the rate of water absorption, increases with the fineness of the flour particles [77].

4.6. Conclusion and Perspectives

The three (3) flours FN, FW, FK of néré (*Parkia biglobosa*) do not show any significant difference at the 5% threshold, for the contents of pH, fibres, phosphorus, manganese, iron, nickel, molybdenum. All other parameters are significantly different at the 5% level. The results obtained show that néré (*Parkia biglobosa*) flours are potential staple foods that could be used in the diet to combat hunger and to provide food security. The results of this study prove that the three (3) flours (FN, FW and FK) are a good source of carbohydrate and could therefore be useful for the body's energy needs. The low moisture content of the three (3) flours (< 8%) would allow the flours to be stored over a long period of time. All three flours contain a level of fibre that is beneficial to people's health. These three

flours are also sources of magnesium, phosphorus, potassium, calcium, manganese, iron, nickel, copper and molybdenum, which are beneficial to the population. The functional properties of the flours, i.e. packed density, water absorption capacity, oil absorption capacity, suggest that néré flours would be suitable for use in food formulations (infant porridges, pastries, cakes, etc.) where these properties are required.

In the future, it would be important to conduct the following research.

-Study the different properties of flours made from néré flour and other flours.

-To propose a food formulation.

References

[1] Diawara, B., Charles, P., Léguet, G., and Niéyidouba, L., 2007. *Nutritional potential of the products of 16 local fruit species in Burkina Faso" January-June 2007, Science et technique, Sciences appliquées et Technologies*, p. 40.

[2] Touré, M., 2018. "The néré, a heritage tree of Upper Guinea." *Belgeo, Belgian Journal of Geography*, Available: http://journals.openedition.org/belgeo/21569

[3] Rateau, N., 1995. *Study of the nutritional value of néré or Parkia food. DESS Nutrition and food in developing countries* vol. 2. University of Montpellier, p. 39.

[4] Lamien, N. and Bamba, A., 2008. "Valorization of Non-timber Forest Products in Burkina Faso: Current situation and perspectives. Income Improvement and Food Security Programme (ARSA) : Cornerstone " Profitable exploitation of non-timber forest products (PFN L)." p. 155.

[5] Tapsoba, A., 2013. "Economic valuation of non-timber forest products in Burkina Faso: the case of Parkia biglobosa (néré)." p. 66.

[6] Sina, S., 2002. *Parkia higlobosa (Jacq) R. Br. Ex G. Don. Card of protabase Oyen, LP.A et Lemmens, R.H.MJ (Edition) PROTA (Plant Resources of Tropical Africa 1 Resources végétales de Afrique tropicales)*. Wageningen, Pays Bas.

[7] Sina, S., 2006. "Reproduction and genetic diversity in Parkia biglobosa (Jacq) G. Don» Thesis of P.H. D University of Wageningen, Wageningen Pays Bas." pp. 6-8.

[8] Bonkoungou, E. G., 1987. *Monograph of the néré, Parkia biglobosa (Jacq) Benth multipurpose agroforestry species*. IRBETI CNRST-Ouagadougou-Burkina Faso, p. 45.

[9] Kassi, Y., Kadjo, J. A., Kouakou, J. C. A., Méa, A., Néné-Bi, S. A., and Ehilé, E. E., 2008. "Anti-hypertensive effect of an aqueous extract of Parkia biglobosa (Mirnosacae) trunk bark on rabbit blood pressure." *Sciences and Nature*, vol. 5, pp. 133-143.

[10] AOAC, 1990. "Official methods preparations and juices. In Halrich K, Editor, Official methods of analysis of AOAC; food composition; additives, natural contaminants." pp. 967-21.

[11] Agbo, N. G., Uebersax, M., and Hosfield, G., 1986. *An efficient extraction technique of sugars from dry edible beans (Phaseolus vulgaris) and estimation in HPLC*. National University, Côte d'Ivoire. Annals series C (sciences) Tome XXI, pp. 169-184.

[12] Dubois, M., Gilles, K. A., Hamilton, J. K., Rebers, P. A., and Smith, F., 1956. "Colorimetric method for determination of sugar and related substances." *Anal. Chem.*, vol. 28, pp. 350-356.

[13] Bernfeld, P., 1955. *Amylase bêta and alpha (assay method), in methods in enzymelogy, Ed.* New-York, USA: Academic Press. pp. 149-154.

[14] AFNOR, 1986. "Collection of French standards. Quality control of dairy products. AFNOR, Paris - la defense."

[15] Wolff, J. P., 1968. *Fat analysis manual*. Paris (France): Azoulayed. p. 519.

[16] FAO, 2002. *Report of the international rice commission. Twentieth session*. Bangkok, Thaïland.

[17] Mohammed, A. I., Ponhamperuma, A. J. P., and Youssef, S. H., 1986. "New chromophore for phytic acid determination." *Cereal Chem*, vol. 63, pp. 475-478.

[18] Singleton, V. L., Orthofer, R., and Lamuala-R, R. M., 1999. "Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent." *Methods Enzymol*, vol. 299, pp. 152-178.

[19] Bainbridge, Z., Tomlins, K., Willings, K., and Westby, A., 1996. *Methods for assessing quality characteristics of non-grain starch-staple. Part 4 Advanced methods*. National Ressources Institute, University of Greenwish, Uk.

[20] Meda, A., Lamien, C. E., Romito, M., Millogo, J., and Nacoulma, O. G., 2005. "Determination of the total phenolic, flavonoid and proline contents in Burkina fasan honey, as well as their radical scavenging activity." *Food Chemistry*, vol. 91, pp. 571-577.

[21] Oadele, A. K. and Aina, J. O., 2007. "Chemical composition and functional properies of winged bean flours produced from two varieties of tigernut (cyperus exculentus)." *African Journal of Biotechnology*, vol. 6, pp. 2473-2476.

[22] Phillips, R. D., Chinnan, M. S., Branch, A. I., Miller, J., and Mewatters, K. H., 1998. "Effect of pre-treatment on functional and nutritional properties of cowpea." *Meal Journal of Food Sciences*, vol. 53, pp. 805-809.

[23] Anderson, R. A., Conway, H. F., Pfeifer, V. F., and Griffin, E. L., 1969. "Rol and intrusson-cooking of grain sorghum grits." *Certicate Sciences Today*, vol. 14, pp. 372-380.

[24] Eke, O. S. and Okobundu, E. N. T., 1993. "Functional properties of african yam bean (sphenostylis stenocarpa) seed flour as affected by processing." *Food chemical*, vol. 48, pp. 337-340.

[25] Fatoumata, H.-B., Pierre, S., and Bréhima, D., 2016. "Evaluation of the quality and acceptability of couscous based on three composite flour formulations enriched with soya (*Glycine max*) and moringa (*Moringa oleifera*)." *Int. J. Biol. Chem. Sci.*, vol. 10, pp. 2497-2510.

[26] CAC, 1985. *Codex standard for wheat flour: Codex stan 152-1985. Codex alimentarius commission*. Italy: CAC Press.

[27] Aguilera, J. M., Del Valle, J. M., and Karel, M., 1995. "Caking phenomenon in amorphosus food powders." *Trends in Food Sciences Technology*, vol. 6, pp. 149-155.

[28] Aryee, F. N. A., Oduro, I., Ellis, W. O., and Afuakwa, J. J., 2006. "The physicochemical properties of flour samples from the roots of 31 varieties of cassava." *Food Control*, vol. 17, pp. 916-922.

[29] Yapi, J. C., Deffan, Z. A. B., Koko, A. C., Diabagate, J. R., Kouame, K. K. B., and Kouame, L. P., 2021. "Influence de la granulometrie sur les caracteristiques physicochimiques et techno-fonctionnelles des farines de souchet (cyperus esculentus l.)." *Agronomie Africaine Sp.*, vol. 33, pp. 239 - 250.

[30] Tortoe, C., Akonor, P. T., Koch, K., Menzel, C., and Adofo, K., 2017. "Physicochemical and functional properties of flour from twelve varieties of Ghanaian sweet potatoes." *Internattional Food and Rescherc Journal*, vol. 24, pp. 2549-2556.

[31] Gutap, V. and Nagar, R., 2008. "Physicochemical and acceptability of rabadi (a fermented soya flour product) as affected by coocking and fermentation time." *International Journal of F and Food Sciences and Tech Nology*, vol. 43, pp. 939-943.

[32] Oulaï, S. F., 2014. "Biochemical and physicofunctional parameters of flours and starches of breadfruit (*Artocarpus altilis*)." Thesis. Nangui Abrogoua University.

[33] Anses, 2021. "Anses. Role of lipids and proteins. Anses.fr."

[34] Niamke, A. M., Assanvo Bomo, J., Rouamba, T., and Djaman, A. J., 2022. "Study of the physico-chemical, functional, granulometric, mineral and antioxidant properties of three (3) flours fs, f40, f50 of young shoots of roan (borassus aethiopum mart.) according to the drying method." *Journal of Experimental Agriculture International*, vol. 44, pp. 15-28.

[35] Djidohokpin, M. E., 2012. *Suitability of the two Fonio varieties for the formulation of complementary food*. Memorandum: Abomey-Calavi University. p. 85.

[36] Chene, C., 2003. "Dietary fibre." *Journal of ADRIANOR Agro-jonction n°33*, pp. 1-8.

[37] Al Dobaib, N., 2009. "Effect of diets on growth, digestibility, carcass and meat quality characteristics of four rabbits breeds." *Sandi Jounal of. Biology. Sci.*, vol. 17, pp. 83-93.

[38] Jalili, T., Wildamn, R. F. C., and Medeiros, D. M., 2000. "Nutraceutical roles of dietary fiber." *Journal of Nutritional Function and Med. Foods*, vol. 2, pp. 19-34.

[39] FAO, 2001. *La nutrition dans les pays en voie de développement*. Genève: FAO. p. 515.

[40] Cruz, J. F., Beavogui, F., and Dramé, D., 2011. *Fonio, an African cereal. Tropical agriculture in your pocket. Quae / Cta / Presses agronomiques de Gembloux*. Versailles, France, p. 175.

[41] Butte, N. F., 1996. "Energy requirement of ints european." *Journal of Clinical Nutrition*, vol. 50, pp. 24-36.

[42] Mebirouk-Boudechiche, L., Cherif, M., Boudechiche, L., and Sammar, F., 2014. "Primary and secondary compound contents of forage shrub leaves from the humid region of Algeria." *Revue de Médecine Vétérinaire*, vol. 165, pp. 344-352.

[43] Wang, S., Moustaid-Moussa, N., Chen, L., Mo, H., Shastri, A., and Su, R., 2014. "New insights into dietary polyphenols and obesity." *J. Nutr. Biochem.*, vol. 25, pp. 1-18.

[44] Fujiki, H., Sueoka, E., Watanabe, T., and Suganuma, M., 2015. "Primary prevention of cancer by green tea and tertiary prevention of cancer by combining green tea catechins and anti-cancer compounds." *J. Cancer Préc.*, vol. 20, pp. 1-4.

[45] Savage, G. P., 2002. "Oxalates in human foods." *Proceedings of the Nutritional Society*, vol. 27, pp. 4-24.

[46] Plaami, S., 1997. "Myoinositol phosphates. Analysis content in foods and effect in nutrition." *Lebensmittel-Wissenschaff and Technologie*, vol. 3, pp. 633-647.

[47] FAO, 2015. *FAO/INFOODs density databases –Version 2.0, Food and Agriculture Organization of the United Nations*. Rome (Italie), p. 25.

[48] Zayas, J. F., 1997. *Water holding capacity of proteins. In: functionality of proteins in food*. Heidelberg, Berlin (Allemagne): Springer. pp. 76-133.

[49] Shittu, T. A., Sanni, L. O., Awonorin, S. O., Maziya-Dixon, B., and Dixon, A., 2005. "Use of multivariate techniques in studying fleur making characteristics of some Cassava Mosaic Disease resistant cassava clones." In *African Crop Science Conference Proceedings.* pp. 621-630.

[50] Nelson-Quartey, F. C., Amagloh, F. K., Oduro, I., and Ellis, W. O., 2007. "Formulation of an infant food based on breadfruit and breadnut." *Act. Horticul*, vol. 757, pp. 212-224.

[51] Marero, L. M., Pajumo, E. M., and Librando, E. C., 1988. "Technologiy of weaning food formulation prepared from germinated cereals and legumes." *J. of Food Sci.*, vol. 53, pp. 1391-1395.

[52] Abulude, F. O., 2004. "Effects of processing on nutritional composition, phytale and functional proprieties of rice (Oryza saliva) flour." *Nigerian Food Joumal*, vol. 22, pp. 97-104.

[53] Falade, K. O. and Okafor, C. A., 2015. "Physical, functional, and pasting properties of flours from corms of two Cocoyam (Colocasia esculenta and Xanthosoma sagittifolium) cultivars." *Journal of Food Science and Technoogyl*, vol. 52, pp. 3440–3448.

[54] Grah, A., Maxwell, B., Beda, M., Yapo, S., Hortense, B., and Dago, G., 2014. "Effect of fermentation time on the physico-chemical properties of maize flour." *International Journal of Rescherches Studies in Biosciences (IJRSB)*, vol. 2, pp. 30-38.

[55] Mbofung, C. M. E., Aboubacar, N. Y., Njintang, A., Bouba, A., and Balaam, F., 2006. "Physicochemical and functional properties of six varieties of taro (Colocasia esculenta L.) flours." *Journal of Food Technology*, vol. 4, pp. 135-142.

[56] Aremu, M. O., Basu, S. K., Gyar, S. D., Goyal, A., Bhowmik, P. K., and Banik, S. D., 2009. "Proximate composition and fonctional properties of Mushroom flours from Ganoderma spp., Omphalolus olearius (DS) Sing. and Hebeloma mesophaeum (pers.) Quél. used in Nasarawa State, Nigeria." *Mal. J. of Nutr.*, vol. 15, pp. 233 - 241.

[57] Siddiq, M., Ravi, R., Harte, J. B., and Dolan, K. D., 2010. "Physical and functional cbaracteristics of selected dry bean (Phaseolus vulgaricus L.) flour." *LWT- J. Food Sci. and Technol.*, vol. 43, pp. 232-237.

[58] Narayana, K. and Narasimga, R. N. M. S., 1982. "Functional propertie of raw and heat processed winged bean flour." *J. of Food Sci.*, vol. 47, pp. 1534-1538.

[59] Adebowale, K. O., Olu-Owolabi, B., Olawumi, E. K., and Lawal, O. S., 2005. "Functional properties of native, physically and chemically modified breadfruit (Artocarpus altilis) starch." *Lnd. Cro. and Prod.*, vol. 21, pp. 343-351.

[60] De Jongh, 2021. "Les aliments les plus riches en magnésium." Available: https://www.la-vie-naturelle.com/blog/post/aliments-riches-en-magnesium.Consultéle29/05/2022

[61] Blancheton, 2018. "10 aliments riches en potassium." Available: https://www.bioalaune.com/fr/actualite-bio/36216/aliments-riches-potassium.Consultéle29/05/2022

[62] Chow, R., 2009. "Potassium-sodium ratios is crucial for heart health." Available: http://www.naturalnews.com/025820sodiumpotassiumhealth.htm/05/05/2013

[63] Kannel, W. B., 1997. "Hazards risks and threat of heart disease from the early stages to symptomatic coronary heart disease and cardiac failure." *Cardiovasc. Ds and Ther*, vol. 11, pp. 199-212.

[64] Daine, 2022. "Phosphore." Available: https://www.doctissimo.fr/html/nutrition/vitamines_mineraux/phosphore.htm

[65] De Jongh, 2021. "Découvrez les aliments les plus riches en calcium." Available: https://www.la-vie-naturelle.com/blog/post/aliments-riches-en-calcium/Consultéle29/05/2022

[66] Bonithon-Kopp, C., Kronborg, O., Giacosa, A., Rath, U., and Faivre, J., 2000. "Calcium and fiber supplementation in prevention of colorectal adenoma recurrence: a randomized intervention trial." *The Lancet*, vol. 356, pp. 1300-1306.

[67] Ofori, H., Charles, T., Paa, T. A., and Jonathan, A., 2016. "Trace metal and aflatoxin concentrations in some processed cereal and root and tuber flour." *International Journal of Food Contamination*, vol. 3, p. 15.

[68] OMS, 1982. *Evaluation of certain foods additives and contaminants twenty-six report of the joint fao/who expert committee on food additives*. Geneva: WHO Technical Report series, No. 683.

[69] Favre, E. "Nutrition expert." Available: https://www.ericfavre.com/lifestyle/fer/consultéle18/05/2022

[70] Senesse, P., Meance, S., Cottet, V., Faivre, J., and Boutron-Ruault, M. C., 2004. "High dietary iron and copper and risk of colorectal cancer: a case –control study in Burgundy." *France. Nutr Cancer*, vol. 49, pp. 66–71.

[71] FAO/WHO, 1984. *Contaminants. In codex alimentarius*. 1st ed. Rome: FAO/WHO, Codex Alimentarius Commission.

[72] Hochberg, J., 2021. Available: https://sante.journaldesfemmes.fr/fiches-nutrition/2753539-cuivre-bienfaits-effets-secondaires-carence-cure-effet-secondaire-surdosage-danger/consultéle18/05/2022

[73] De Jongh, 2022. "Les sources naturelles du molybdène." Available: https://www.la-vie-naturelle.com/blog/post/molybdene)(Consulté

[74] CSS Conseil Supérieur de la Santé, 2016. "Recommandations nutritionnelles pour la Belgique. Bruxelles: Avis." p. 202.

[75] Zubiria, 2018. "Manganèse : tout sur ce minéral essentiel." Available: https://www.passeportsante.net/fr/Nutrition/PalmaresNutriments/Fiche.aspx?doc=manganese),consultéle09/09/2022

[76] CSS Conseil Supérieur de la Santé, 2009. "Recommandations nutritionnelles pour la Belgique. Révision 2009. Bruxelles : CSS, 2009. Avis."

[77] Feillet, P., 2000. *Wheat grains, composition and use*. Paris: INRA. p. 308.