SJIF Impact Factor: 5.464

WORLD JOURNAL OF ADVANCE HEALTHCARE RESEARCH

ISSN: 2457-0400
Volume: 6.
Issue: 3
Page N. 140-149
Year: 2022

Original Article www.wjahr.com

PHYSICAL, BIOCHEMICAL AND NUTRITIONAL CHARACTERISTICS OF THE SEEDS OF *PTEROCARPUS SANTALINOIDES* LHER. EX DE (PAPILIONOIDEAE), A SPONTANEOUS PLANT FOUND IN CÔTE D'IVOIRE

Pierre Etche Etche[1], Irene Ahou Kouadio[2], Yolande Dogore Digbeu[3] and Edmond Ahipo Due[1]*

[1]Laboratory of Biocatalysis and Bioprocessing, Nangui Abrogoua University, 02 BP 801 Abidjan 02, Côte D'ivoire.
[2]Laboratory of Biotechnology Agriculture and biological Resources, Felix Houphouet Boigny University, 22 BP 582, Abidjan 22, Côte D'ivoire.
[3]Laboratory of Nutrition and Food Security, Nangui Abrogoua University, 02 BP 801 Abidjan 02, Côte D'ivoire.

Received date: 08 January 2022 **Revised date:** 28 February 2022 **Accepted date:** 01 March 2022

***Corresponding Author: Prof. Edmond Ahipo Due**
Laboratory of Biocatalysis and Bioprocessing, Nangui Abrogoua University, 02 BP 801 Abidjan 02, Côte D'ivoire.
Email Id: ahipoedmond@yahoo.fr

ABSTRACT

Various parts of spontaneous plants are consumed in several countries including Côte d'Ivoire. *P santalinoides* is one of these spontaneous plants whose seeds are consumed mainly in rural areas of Côte d'Ivoire. In order to valorize the seeds of *Pterocarpus santalinoides*, studies on its physical, biochemical and nutritional characteristics were carried out. The physical characteristics concerned the mass, length, width, thickness and circumference of the fruits and seeds. Thus, the mass determined was 6.06 ± 1.47 g for the fruit and 3.29 g ± 2.52 g for the seed. The length was 3.71 ± 0.63 cm for the fruit and 1.95 ± 0.49 cm for the seed. The width was 3.15 ± 0.29 cm for the fruit and 1.03 ± 0.06 cm for the seed. The thickness value was 2.22 ± 0.31 cm for the fruit and 1.19 ± 0.15 cm for the seed and the recorded circumferences were 9.16 ± 0.89 cm and 4.18 ± 0.31 cm for the fruit and seed respectively. The biochemical and nutritional characteristics were only recorded for the seeds. The results obtained indicated variability among the flours. Thus, the moisture content ranged from 8.49 to 9.27%. The pH ranged from 5.85 to 6.05. The acidity ranged from 0.21 to 0.43%. The crude fiber content varied between 2.06 and 3.17% and the lipid content varied between 1.38 and 1.42%. The protein content of the flours ranged from 11.69 to 14.21%. These contents were lower than those of soya, beans and lentils. In addition, the ash content was between 3.52 and 3.96%. The total carbohydrate data ranged from 71.92 to 74.15%. The starch content was 64.04%, which is within the range of starch content of cereal grains. As for soluble sugars, the total sugar content varied between 7.80 and 8.56% and that of reducing sugars was between 0.37 and 0.88%. The energy value varied between 355.73 and 357.28 Kcal per 100 g of flour. Regarding the amino acid composition, of the four amino acids obtained, arginine (1.47 to 2.85 g/100g protein) and valine (3.68 to 4.60 g/100g protein) are essential amino acids, while cysteine (0.54 to 1.64 g/100g protein) and proline (9.20 to 14.22 g/100g protein) are non-essential amino acids. Concerning the mineral composition, magnesium was the mineral with significant values (103.12 to 105.82 mg/100g) in contrast to copper (0.91 to 1.06 mg/100g). On the other hand, the calcium contents recorded (50.85 ± 0.01 to 59.63 ± 0.01) were lower than that of whole milk. The study of the biochemical and nutritional properties of *P santalinoides* seeds gave an insight into the possible uses of these seeds.

KEYWORDS: Physical, biochemical, nutritive, *Pterocarpus santalinoides*, spontaneous plant.

1- INTRODUCTION

Nowadays, forest species are abundant in natural ecosystems or reconstituted formations. They contribute remarkably through their Non-Timber Forest Products (NTFPs) to human health and food (Ayena et *al*., 2016). In addition to cultivated plants, several thousand little-known wild plants have cultural importance and high economic potential for medicine, food, energy, construction and crafts. In Africa, many of these species are used daily by farmers. In fact, these plants provide a full diet in times of food shortage (Herzog, 1992). However, in both developed and underdeveloped countries there is a pressing need for new food plants to meet the nutritional needs of the ever-growing populations (Diallo et al., 2015). The failure to meet these needs exposes a section of the population in these countries to undernutrition and often malnutrition. Indeed, protein deficiency is the most common form of malnutrition (Mauron, 1973). The cereals and tubers available to a large part of the population are relatively less rich in protein. Due to economic difficulties or impoverishment, proteins of animal origin are still inaccessible to a large part of the population (Diallo et al., 2015). As a result, legumes remain promising sources of vegetable protein. Thus, several studies on the nutritional values of legumes and derived products have been reported. However, the data concerning the seeds of *Pterocarpus santalinoides* are less known. Yet, this plant is counted among the legumes and its seeds are consumed as much as groundnut seeds by some people in West African countries, notably Benin (Ayéna and Agassounon, 2015). Due to the poor availability of information on the biochemical and nutritional properties of *Pterocarpus santalinoides* seeds found in Côte d'Ivoire, the study of these different parameters seems necessary. The present study aims to determine the physical, biochemical and nutritional characteristics of the flours obtained from the seeds of these fruits.

2- MATERIALS AND METHODS

2.1- Plant material

The biological material used for this study is mature seeds of *P santalinoides.*

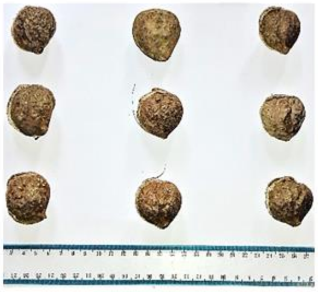

Figure 1: Fruits of *P santalinoides*

Figure 2: Seeds of *P santalinoides* with seed coats

Figure 3: Seeds of *P santalinoides* without seed coats

2.2- Methods

2.2.1- Sampling

The fruits of *P santalinoides* were collected randomly in a field in Monga, a locality located in the department of Alépé in the south-east of Côte d'Ivoire, and then transported the same day in net bags to the biocatalysis and bioprocesses laboratory of Nangui Abrogoua University.

2.2.2-Determination of physical characteristics of fruits and seeds

2.2.2.1- Determination of masses

The masses of 100 fruits and 100 seeds of *Pterocarpus santalinoides* were determined using a 0.001 g precision analytical balance (MT-200, METLAR, Toledo, Spain).

2.2.2.2- Measurement of dimensions

The dimensions of 100 fruits and 100 seeds of *Pterocarpus santalinoides* were measured using a caliper with a measuring range of 0 to 150 mm with a precision of 0.05 mm. The dimensions measured were length, width and thickness. The circumference was measured with a measuring tape (Hoba, 2019).

2.2.3- Flour preparation

The preparation of *P santalinoides* flours was done in several stages

Once in the laboratory, the fruits were sorted, washed and drained. The fruits were then dehulled with a stainless steel knife by slicing them lengthwise at a quarter of their lower part. In addition, three (03) rinses with distilled water and then drying in an oven (45°C for 72 hours) were necessary after obtaining the different seeds previously weighed (seeds with seed coats, seeds without seed coats). Further on, grinding was done in order to reduce the dried seeds to more or less fine particles so as to facilitate the obtaining of flour. Again, the sieving was done using a 250 µm sieve to obtain fine particles. The flours produced were packaged in hermetically sealed jars and stored in better conditions until their next use.

2.2.4- Determination of biochemical and nutritional characteristics of *P santalinoides* seed flours

2.2.4.1- Determination of moisture content

Moisture and dry matter contents were determined from the mathematical relationships proposed by AOAC (1990)

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

$$DMC\ (\%) = 100 - MC\ (\%)$$

With
MC: moisture content
M_1: mass of crucible + sample (before steaming)
M_2: mass of crucible + sample (after steaming)
Ms: mass of the sample
DMC: dry matter content

2.2.4.2- Determination of pH and total titratable acidity

2.2.4.2.1-pH

The pH was defined according to the method of Sadler and Murphy (2010).

2.2.4.2.2- Total titratable acidity

The total titratable acidity was deduced according to the method of Sadler and Murphy (2010).

The calculation of the percentage of total titratable acidity was carried out by the following mathematical expression

$$TTA\ (\%) = \frac{N \times V_1}{V_2} \times 100$$

With:
TTA: total titratable acidity
V_1 : volume of titrant (ml)
V_2 : sample volume (ml)
N : normality of the titrant solution (0.1N)

2.2.4.3- Determination of ash content

The ash content of the different flours (FaT and FasT) of *P santalinoides* seeds was determined according to the AOAC method (1995). The mathematical formula below was used to calculate the ash content (TC)

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

With
Ms: mass (g) of the sample approximately 5 g
M2: mass (g) of the whole (crucible + ash) after incineration.
M1: mass (g) of the set (crucible + powder) before incineration.
AC: ash content

2.2.4.4- Determination of crude fiber content

Crude fiber was determined according to the AOAC (1995) method. The fiber content was determined according to the following relationship.

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

With
CF: crude fiber
M_1: mass of dried residue
M_2: mass of the ash obtained
Ms: mass of the sample

2.2.4.5- Extraction and determination of ethanosoluble sugars

The ethanosoluble sugars of the samples were extracted using the technique described by Martinez-Herrera et al. (2006)

Determination of total sugars

Total sugars were determined according to the method reported by N'Guetta (2016) using phenol and concentrated sulfuric acid.

Determination of reducing sugars

Reducing sugars were determined according to the method of Yao et al. (2015) using 3,5 dinitrosalicylic acid (DNS).

2.2.4.6- Determination of protein content

Crude protein is determined from the determination of total nitrogen according to the method of Kjeldhal (BIPEA, 1976) and the total protein content was expressed as percentage of mass by the following formulas

$$Total\ nitrogen\ (\%) = \frac{V_1 - V_0 \times N \times M_N}{Ms} \times 100$$

$$Total\ protein\ (\%) = 6{,}25 \times Total\ nitrogen\ (\%)$$

With
V_0: volume of sulphuric acid (0.1N) added for the blank test;
V_1: volume of sulphuric acid (0.1N) added for the test (sample);
N: nitrogen level.
M_N: normality of the sulphuric acid solution.
Ms: mass of the test sample in grams.

2.2.4.7- Determination of lipid content

The method used is the one described by the French standard AFNOR (1986) using the Soxhlet as extractor. The lipid content was expressed as a percentage by mass as follows

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

With

L: lipid content

Ms: mass of the sample

M_1: mass of the empty flask

M_2: mass of flask + oil

2.2.4.8- Determination of total carbohydrate content

The total carbohydrate content of the flours was determined using the FAO (1998) method as follows

$$\text{Total Carbohydrates } (\%) = 100 - [\%\ \text{Moisture} + \%\ \text{Protein} + \%\ \text{Lipids} + \%\ \text{Ashes}]$$

2.2.4.9- Calculation of the energy value

The energy value was calculated according to the following mathematical formula.

$$\text{Energy value (Kcal)} = (9 \times \%\ \text{lipids}) + (4 \times \%\ \text{protein}) + (4 \times \%\ \text{Carbohydrates})$$

2.2.4.10- Determination of starch content

The starch content was determined according to the relationship given by Englyst et al (1992).

$$\text{Starch } (\%) = [\text{Total Carbohydrates } (\%) - \text{Total sugar } (\%)] \times 0,9$$

2.2.4.11- Amino acid determination and identification

The extraction of total amino acids was carried out according to the modified method of Deguine and Hau (2001) using HPLC.

Quantification

The concentrations were determined from the average of the peak areas of the reference (control) solutions. The EC concentration of the samples expressed in mg/100g protein is given by the following formula

$$CE = \frac{\text{Aire E} \times \text{CT}}{\text{Aire T}}$$

With

CS: concentration of the sample

T area: peak area of the control

E area: peak area of the sample

CC: control concentration

2.2.4.12- Quantification of mineral elements

The quantification of minerals was carried out at the Centre d'Analyses et de Recherche (CAR) of the PETROCI laboratory (Abidjan, Côte d'Ivoire). The flours were incinerated at 550°C for eight hours (08 h) in a muffle furnace. The ash obtained was used to carry out the mineral profile of the samples using the D.C.AR. Variable Pressure Scanning Electron Microscope (SEM). (FEG Supra 40 VP Zeiss SEM), equipped with an X-ray detector (OXFORD Instruments) connected to an EDS microanalysis platform (Inca Dry Cool, without liquid nitrogen). The data obtained was transferred to a file that could be used in Excel or Word.

2.3- Statistical analysis of the data

All measurements were carried out in triplicate. Statistical analyses of the data were performed using Statistica version 7.1 software. Comparisons of means were determined using Student's t test and statistical significance was defined at $p \leq 0.05$.

3- RESULTS

3.1- Physical characteristics of fruits and seeds

The physical characteristics (mass, length, width, thickness and circumference) of the fruits and seeds of *Pterocarpus santalinoides* were determined. The values obtained showed that both fruits and seeds had different measurements (Table 1). The fruit has a mass of 6.06 ± 1.47 g, length of 3.71 ± 0.63 cm and width of 3.15 ± 0.29

cm. The seed was 1.95 ± 0.49 cm long, 1.03 ± 0.06 cm wide and had a mass of 3.29 ± 2.52 g.

Table 1: Physical characteristics of *P santalinoides* fruits and seeds.

	Properties				
	Weight(g)	Length(cm)	Width(cm)	Thickness (cm)	Circumference (cm)
Fruit	6.06 ± 1.47	3.71 ± 0.63	3.15 ± 0.29	2.22 ± 0.31	9.16 ± 0.89
Seed	3.29 ± 2.52	1.95 ± 0.49	1.03 ± 0.06	1.19 ± 0.15	4.18 ± 0.31

3.2- Biochemical and nutritional characteristics of flours

3.2.1- Biochemical characteristics

The results of the analyses on the biochemical composition of the flours studied were given in Table 2.

The average contents of moisture (8.49 ± 0.01% and 9.27 ± 0.08%), protein (14.21 ± 0.07% and 11.69 ± 0.12%), ash (3.96 ± 0.07% and 3.52 ± 0.06%), total carbohydrates (71.92 ± 0.07% and 74, 15 ± 0.06%), and fiber (3.17 ± 0.1% and 2.06 ± 0.06%) respectively for flour with seed coatings (FaT) and flour without seed coatings (FasT) were statistically different at the 5% threshold. This difference was also seen with the levels of total titratable acidity (0.43 ± 0.06% and 0.21 ± 0.02%), total sugars (8.56 ± 0.03% and 7.80 ± 0.03%), reducing sugars (0.88 ± 0.02% and 0.37 ± 0.01%) as well as pH (5.85 ± 0.02 and 6.05 ± 0.02). However, no statistical differences were observed in the lipid content (1.42 ± 0.02% and 6.05 ± 0.02%) and energy values (357.28 ± 1.00 Kcal/100g and 355.73 ± 0.07 Kcal/100g). The percentage of starch was determined with the flour without hulls and showed a rate of 64.04 ± 0.25%.

Table 2: Biochemical composition of flour with seed coat and flour without seed coat.

Parameters	Types of flours		
	FaT	FasT	p-value
Moisture (%)	8.49 ± 0,01[a]	9.27 ± 0.08[b]	0.000
pH	5.85 ± 0.02[a]	6,05 ± 0.02[b]	0.000
Total titratable acidity (%)	0.43 ± 0,06[b]	0.21 ± 0.02[a]	0.004
Crude fibre (%)	3.17 ± 0,1[b]	2.06 ± 0,06[a]	0.000
Lipids (%)	1.42 ± 0,02[a]	1.38 ± 0,03[a]	0.676
Proteins (%)	14.21 ± 0.07[b]	11.69 ± 0.12[a]	0.000
Ashes (%)	3.96 ± 0.07[b]	3.52 ± 0.06[a]	0.001
Total carbohydrates (%)	71.92 ± 0.07[a]	74.15 ± 0.06[b]	0.000
Starch (%)	-	64.04 ± 0.25	-
Total sugars (%)	8.56 ± 0.03[b]	7.80 ± 0.03[a]	0.000
Reducing sugars (%)	0.88 ± 0.02[b]	0.37 ± 0.01[a]	0.000
Energy value (Kcal/100g ms)	357.28 ± 1.00[a]	355.73 ± 0.07[a]	0.052

Values are the mean ± standard deviation of three measurements (n = 3). Means ± standard deviations with different letters on the same line are significantly different at the 5% level.

FaT *:* flour with seed coat ; FasT*:* flour without seed coat

3.2.2- Nutritional characteristics

3.2.2.1- Amino acid composition of *Pterocarpus santalinoides* flours

The study of amino acid composition identified four amino acids, two of which were essential (Arginine and Valine) and two non-essential (Cysteine and Proline). Arginine was the most abundant essential amino acid regardless of the type of flour, as was proline for the non-essential amino acids (Table 3). Significance was seen when comparing the values of the two flours ($p \leq 0.05$).

Table 3: Amino acid composition of *Pterocarpus santalinoides* flours.

Amino acids	R.time (min)	Types of flours		
		FaT	FasT	p-value
Cysteine (g/100g proteins)	3.02 – 3.10	1.64 ± 0.01[b]	0.54 ± 0.01[a]	0.000
Proline (g/100g proteins)	3.15 – 3.19	14.22 ± 0.02[b]	9.20 ± 0.01[a]	0.000
Valine (g/100g proteins)	3.31 – 3.41	3.68 ± 0.02[a]	4.60 ± 0.01[b]	0.000
Arginine (g/100g proteins)	3.53 – 3.49	2.85 ± 0.01[b]	1.47 ± 0.01[a]	0.000

Values are the mean ± standard deviation of three measurements (n = 3). Means ± standard deviations with different letters on the same line are significantly different at the 5% level.

FaT: flour with seed coat; FasT: flour without seed coat; R. time (min): retention time in minutes

3.2.2.2- Mineral composition of *Pterocarpus santalinoides* flours

The mineral contents of the flours are recorded in Table 4. Statistical analysis of the mineral composition of the flours revealed significant differences ($p \leq 0.05$). Magnesium (Mg) was the predominant mineral, with contents ranging from 103.12 mg/100g to 105.82 mg/100g for Fast and Fat flours respectively, while copper (Cu) was the least abundant mineral with contents ranging from 0.91 to 1.06 mg/100g. With regard to Na/K; Ca/P ratios, the results showed values below 1 and above 1, respectively.

Table 4: Mineral composition of *Pterocarpus santalinoides* flours.

Minerals	Types of flours		
	FaT	FasT	p-value
Calcium (mg/100g ms)	59.63 ± 0.01^b	50.85 ± 0,01^a	0.000
Phosphorus (mg/100g ms)	22.71 ± 0.01^b	19.54 ± 0.01^a	0.000
Magnesium (mg/100g ms)	105.82 ± 0.02^b	103.12 ± 0.01^a	0.000
Potassium (mg/100g ms)	27.48 ± 0.01^b	25.75 ± 0.02^a	0.000
Sodium (mg/100g ms)	21.39 ± 0.01^b	13.53 ± 0.02^a	0.000
Manganese (mg/100g ms)	1.10 ± 0.01^b	1.05 ± 0.01^a	0.000
Zinc (mg/100g ms)	1.95 ± 0.01^b	1.64 ± 0.01^a	0.000
Copper (mg/100g ms)	1.06 ± 0.01^b	0.91 ± 0.01^a	0.000
Iron (mg/100g ms)	16.45 ± 0.01^b	11.13 ± 0.01^a	0.000
Na/K	0.78	0.53	
Ca/P	2.63	2.60	

Values are the mean ± standard deviation of three measurements (n = 3). Means ± standard deviations with different letters on the same line are significantly different at the 5% level.
FaT: flour with seed coat; FasT: flour without seed coat

4- DISCUSSION

The dimensions of the fruits and seeds of *Pterocarpus santalinoides* in terms of length (3.71 cm ; 1.95 cm), width (3.15 cm; 1.03 cm) and thickness (2.22 cm ; 1.19 cm) were close to those of the fruits and seeds of the morphotype 1 of *Pterocarpus santalinoides* found in Benin (Ayéna and Agassounon, 2015). The differences observed in the dimensions of the fruits and seeds of *Pterocarpus santalinoides* could be due to the agronomic value of the soil, the climate and the delay in flowering. Also, rainfall would have a determining effect on fruit size (Ahouansou et *al*., 2008).

The moisture content is an indicator of quality and is an important indicator of the flour's suitability for preservation. Indeed, a high moisture content in flour, above 12%, favours the proliferation of micro-organisms responsible for its deterioration. On the other hand, a low moisture content of the flour is beneficial because it can be preserved for a relatively long period (Cissé, 2013). The calculated humidity levels are relatively low and range from 8.49 to 9.27%.

The differences in water content observed could be attributed to their physicochemical dissimilarities. The values were between those performed on raw and processed bean (Phaseolus vulgaris L.) flours by Audu and Aremu (2011) who reported values ranging from 2.30% to 9.2%.

The pH of the flours were slightly acidic (5.85 ± 0.02 to 6.05 ± 0.02). The total titratable acidity measured was between 0.21 ± 0.02% and 0.43 ± 0.06%. This acidity of the flours would reflect the presence of organic acids (Sengev et *al*., 2013). Consequently, the flours studied could be stored for a long time without risk of microbial alterations.

Dietary fiber is a fundamental component of diets. It facilitates bowel movements and helps manage body weight. In addition, fiber reduces the risk of coronary heart disease, heart disease, high blood pressure, diabetes, colon and breast cancer (Ishida et *al*., 2000; Oyeyinka and Afolayan, 2019). The flours studied had fiber contents (3.17 ± 0.1% for FaT and 2.06 ± 0.06% for FasT) relatively closed (2.57 to 4.01%) to those of the seeds of different voandzou varieties studied by Diallo et *al*. (2015). The difference noted would be related to the insoluble and soluble fiber content of the flours Ait et *al*. (2016).

The average lipid composition of the analysed flours varied between 1.38 ± 0.03% for the flour without seed coat and 1.42 ± 0.02% for the flour with seed coat. The results obtained were justified by those of Mebdoua (2011) which varied from 1.35% to 1.66% but remained lower than those of Audu and Aremu (2011). These low lipid levels would facilitate the extraction of proteins and starch as no delipidation would be necessary.

The crude protein analysis indicated that there was a significant difference between the values of the flours studied. This difference would be due to the proportion of seed coat contained in the flour with seed coat (FaT). In reality, the protein content was justified along a distribution gradient. This gradient is increasingly important from the peripheral to the central regions of the grain (Bénétrix and Autran, 1997), hence the difference observed between the values obtained. The results obtained were lower than those for soybean (36.5%), bean (23.4%) and lentil (24.6%) (Rémond and Walrand, 2017). However, according to Abdou et *al*. (2012), edible plants whose protein content provides 12% of the caloric value, were a good source of protein. Therefore, *P santalinoides* flours could be beneficial in infant feeding.

Ash is useful in that the inorganic mass is related to the mineral composition and furthermore helps to retard microbial growth (Oyeyinka and Afolayan, 2019). The difference found would be justified by the uneven distribution of minerals in different parts of the plant (Nwofia et *al*., 2012). The calculated ash contents (3.96 ± 0.06% and 3.52 ± 0.06%) were closed to that (3.25%) obtained by Mazahid et *al*., (2013) with voandzou seeds from Sudan.

Carbohydrates are the main source of energy for the body and are the key ingredient of cells. The total carbohydrate contents (71.92 ± 0.07% and 74.15 ± 0.06%) of the analysed flours were higher than those of the flours of the seven voandzou cultivars (54.05 and 64.50%) determined by Diallo et *al*. (2015). Nevertheless, these levels are close to those reported by Aremu et *al*. (2005). The carbohydrate content of *P. santalinoides* seeds can be a good source of calories to combat marasmus and can be used in infant feeding (Tchumou et *al*., 2019).

Starch is an abundant, renewable, inexpensive nutrient that has multiple functions in foods as a thickener, gelling agent, binder in its granular starch starch form and as a sweetener in its hydrolysed form (Mbougueng, 2009). The percentage of starch recorded (64.04 ± 0.25%) was lower than that of ukpa seeds (67.72%), one of the varieties of Phaseolus lunatus found in Nigeria (Ezeagu and Ibegbu, 2010). On the other hand, this percentage falls within the range of starch content of cereal seeds (30 to 70%) (Mbougueng, 2009).

The levels of reducing sugars in the dry matter of the *Pterocarpus santalinoides* flours studied were very low compared to the levels of total sugars contained in these flours. Shrestha et *al*. (2002) also obtained identical values (21.0 ± 1.1% total sugars and 3.1 ± 0.1% reducing sugars) with whole soybean meal, showing that the fraction of reducing sugars in a legume was very low compared to that of total sugars. These results therefore suggest the use of these flours in the preparation of bakery and pastry products.

The amino acid profile indicated a total of four amino acids, two of which were essential and two non-essential. Essential amino acids are those that the body necessarily needs but is unable to synthesise. Non-essential amino acids are those that the body does not necessarily need because it can synthesise them (Motta et *al*., 2020).

The determined proline content was higher than those of groundnut (5.48 g/100g protein) and potato pea (6.25 g/100g protein). However, the cysteine, arginine and valine contents remained lower (Abdualrahman et *al*., 2015).

Minerals are essential compounds in the diet because of their physiological and metabolic function in the body. Analysis of the mineral composition of flours from *Pterocarpus santalinoides* seeds revealed that they contain proportions of so-called macroelements (Ca (50.85 to 59.63 mg/100g), P (19.54 to 22.71 mg/100g), Mg (103.12 to 105.82 mg/100g), K (5.75 to 7.48 mg/100g), Na (13.53 to 21.39 mg/100g)) and minerals known as trace elements (Mn (1.05 to 1.10 mg/100g), Zn (1.64 to 1.95 mg/100g), Cu (0.91 to 1.06 mg/100g), Fe (11.13 to 16.45 mg/100g)) Calcium plays an indispensable role in heart contraction, conduction of nerve impulses, blood clotting, regulation of body pH as well as stimulation of insulin secretion (Skalli-Pariat, 2017). However, the recorded calcium levels were about twice as low as in whole milk (125 mg/100 g) (Saulais, 2000). Phosphorus is a constituent of bones and cell membranes. It regulates neuromuscular excitability and is considered an energy "fuel" for the body. It also ensures acid-base balance and is involved with calcium in tooth formation and bone development in children (Makinde and Akinoso, 2013; Skalli-Pariat, 2017). Magnesium is an intracellular cation. The Mg2+ ion is involved in regulation, cell permeability and neuromuscular excitability. The average intake of magnesium is between 360 and 420 mg/d. A deficiency in this mineral would be responsible for muscle cramps, palpitations, vomiting and insomnia (Touati-Mecheri, 2002; Avensac, 2018). With regard to potassium and sodium, potassium ensures the regulation of the heartbeat and is used in the mechanism of muscle contraction. In addition, it plays a fundamental role with sodium in maintaining the electrical potential in membrane cells and in the conduction of nerve impulses (Taylor, 2003). Sodium is the major cation in the extracellular, plasma and interstitial environment. As such, it maintains the ionic balance of the cell and the balance between bases and acids in association with other ions. In addition, the distribution of water between the extra- and intracellular medium, the transmission of nerve impulses and muscle contraction are all done through sodium (Skalli-Pariat, 2017). Copper has a complementary action to that of manganese. The combination of these two trace elements is used in ligament hyperlaxity, delayed ossification or in infectious manifestations (Picaud, 2017). Zinc is a mineral that is important in the synthesis of nucleic acids, proteins and amino acids. Moreover, it catalyses the reactions of certain metalloactivated enzymes and is involved in the metabolism of polyunsaturated fatty acids. Iron is a constituent of haemoglobin and enables the transport and storage of oxygen (Skalli-Pariat, 2017). Minerals are essential compounds for life. As a result, their deficiencies lead to the impairment of one or more body functions. Overall, the mineral composition of *Pterocarpus santalinoides* flours was closed +to that of raw bean (Phaseolus vulgaris L.) seed flour (Audu and Aremu, 2011). However, this composition is still lower than that of flour from cowpea cultivars (Dolichos lablab var. vulgaris L.) (Kalpanadevi and Mohan, 2013).

It has been reported that the Na/K ratio is of great importance for the prevention of hypertension. Thus, values below 1 are recommended. The Na/K ratio of Fat (0.78) and Fast (0.53) are less than 1. Regarding the Ca/P ratio, it is considered "good" if it is greater than 1 and "poor" if it is less than 0.5 (Kalpanadevi and Mohan, 2013). *Pterocarpus santalinoides* seed meals would serve as good sources of minerals for bone formation, with Ca/P ratios ranging from 2.60 to 2.63. The difference observed would be related to the mineral proportion of each part of the seeds. Indeed, according to Mandizvo and Odindo (2019) it is obvious that minerals are present in all parts of the legume seed. However, they are not stored in equal proportions.

5- CONCLUSION

This study has shown that *P. santalinoides* seeds were a significant source of nutrients regardless of the form in which the seeds were used. Based on the physicochemical composition, *P santalinoides* seeds could be used for food formulation. Thus, the consumption of these seeds could contribute on the one hand to the improvement of the nutritional and sanitary state of the users and on the other hand to the improvement of their incomes through the development of new products. Consequently, the conservation and valorisation of these seeds remain a necessity.

ACKNOWLEDGEMENTS

The authors would like to thank all those who took part in the realization of this work, namely the Laboratory of Biocatalysis and Bioprocesses of the University Nangui Abrogoua, as well as the teachers who willingly accepted to share their knowledge.

Conflict of interest

The authors have not reported any conflicts of interest.

REFERENCE

1. Abdou H. M. K., Maman B. G. O. & Maman B. M., Caractérisation de la végétation ligneuse du terroir villageois de Sina Kouara (Niger). Mémoire de licence en biodiversité et gestion de l'environnement. Faculté des Sciences et Techniques de l'Université Abdou Moumouni, Niamey, Niger, 2012; 29.
2. Abdualrahman Y. A. M., Ali O. A., Elkhalifa A. E. & Ma H. Chemical, minerals, fatty acid and amino acid compositions of sudanese traditional khemiss-tweria supplemented whith peanut and bambara groundnuts. *American Journal of Food Technology*, 2015; 10(3): 100-108.
3. AFNOR. Recueil de normes françaises, Corps gras, graines oléagineuses, produits dérivés. AFNOR Ed, Paris, 1986; 527.
4. Ahouansou H. R., Sanya A. E., Bagan C. G & Foudjet E. A. Etude de quelques caractéristiques physiques des noix et graines de karité produites au Bénin. *Science et technique, Sciences appliquées et Technologies*, 2008; 2 (1 et 2): 29-38.
5. Ait S. D., Ait C. O., Bouderoua K. & Selselet-Attou G. Place des légumes secs dans l'alimentation humaine-atouts nutritionnels et impacts sur la santé. *Forum Régional pour le Développement des Légumineuses Alimentaires*. Université de Mostaganem 28, 29 et 30 Novembre 2016, Mostaganem, Algérie, 2016; 1-5.
6. AOAC. Official methods of Analysis of AOAC International, 16th ed. AOAC International Arlington.VA, 1995; 250.
7. AOAC. Association of Official Analytical Chemists Method of Analysis; 15th edition, Washington D.C., 1990; 222-236.
8. Aremu M. O., Olaofe O. & Akintayo E. T. Nutritional qualities assessment of the presence of hull in some nigerian underutilized legume seeds. *Bulletin of Pure and Applied Sciences*, 2005; 24(1-2): 47-52.
9. Audu S. S. & Aremu M. O. Nutritional composition of raw and processed pinto bean (*Phaseolus vulgaris* L.) grown in Nigeria, *Journal of Food, Agriculture & Environment*, 2011; 9(3 et 4): 72-80.
10. Avensac M. Le magnésium dans la prise en charge du stress à l'officine. Thèse de Doctorat de l'Université Toulouse III Paul Sabatier, Toulouse, France, 2018; 95.
11. Ayéna A. C. & Agassounon T D. M. Valorisation de *Pterocarpus santalinoides* L'Hér. Ex De. (Papilionoideae), une plante alimentaire et médicinale utilisée au Bénin en Afrique de l'Ouest. *Journal of Applied Biosciences*, 2015; 90: 8377-8386.
12. Ayena A. C., Agassounon D. T. M., Assogbadjo A. E., Adoukonou S. H., Mensah G. A., Agbangla C. & Ahanhanzo C. Usages et vulnérabilité De *Pterocarpus santalinoides* L'her. Ex De (Papillionoidae), une Plante utilisée dans le traitement des Gastro-Entérites dans le Sud du Bénin. *European Scientific Journal*, 2016; 12(6): 218-231.
13. Bénétrix F. & Autran J-C. Synthèse protéique dans les grains et les graines. In : *Assimilation de l'azote chez les plantes ; aspects physiologique, biochimique et moléculaire*, *INRA*, Paris, France, 1997; 307-325.

14. BIPEA. Recueil de méthodes d'analyses des communautés européennes. BIPEA, Gennevillier, 1976; 51-52.
15. Cissé M. Caractérisation biochimique et nutritive des grains de variétés de maïs (*Zea mays*) QPM et ordinaires cultivées en Côte d'Ivoire. Thèse de Doctorat, université Félix Houphouët Boigny, 2013; 121.
16. Deguine J. P. & Hau B. Influence de la plante sur Aphis gossypii : quelques résultats de la recherche menée au Cameroun. Cirad-ca, Programme coton, TA 72/09, 34398 Montpellier Cedex 5, France, 2001.
17. Diallo K. S., Koné K. Y., Soro D., Assidjo N. E., Yao K. B., Gnakri D. Caractérisation biochimique et fonctionnelle des graines de sept cultivars de voandzou [*Vigna subterranea* (L.) Verdc. Fabaceae] cultivés en Côte d'Ivoire. *European Scientific Journal*, 2015; 11(27): 1857-7881.
18. Englyst H. N., Kingman S. M. & Cummings J. H.. Classification and measurement of nutritionally important starch fractions. *European Journal of Clinical Nutrition*, 1992; 46(2): 333-350.
19. Ezeagu. I. E. & Ibegbu M. D. Biochemical composition and nutritional potential of *ukpa*: a variety of tropical lima beans (*Phaseolus lunatus*) from nigeria – a short report. *Polish Journal of Food and Nutrition Sciences*, 2010; 30(3): 231-235.
20. FAO/WHO, 1998. The application of risk communication to food standards and safety matters. Report of a Joint FAO/WHO Expert Consultation. Rome, 2010; 32.
21. Grivetti L., Frentzel C. J., Ginsberg K. E., Howell K. L. & Ogle B. M. Bush foods and edible weeds of agriculture: perspectives on dietary use of wild plants in Africa, their role in maintaining human nutritional status and implications for agricultural development. In: Akhtar, R. (ed.): Health and disease in tropical Africa. Harwood, London, 1987; 51-81.
22. Herzog M. F. Etude biochimique et nutritionnelle des plantes alimentaires sauvages dans le sud de V-Baoulé, Côte d'Ivoire. Thèse de Doctorat, Ecole Polytechnique Fédérale Zurich, Zurich, Suisse, 1992; 135.
23. Hoba F. M. A. Caractéristiques nutritionnelles des arilles de l'Ackee (*Blighia sapida* K. Koeinig, 1782) et utilisation de leurs tourteaux en production de caille japonaise (*Coturnix japonica* Temminck et Schlegel, 1849) en Côte d'Ivoire. Thèse de Doctorat de l'Université Nangui Abrogoua, Abidjan, Côte d'Ivoire, 2019 ; 247.
24. Ishida H., Suzuno H., Sugiyama N., Innami S., Todokoro T. & Maekawa A. Nutritional evaluation of chemical component of leaves, stalks and stems of sweet potatoes (Ipomoea batatas poir). *Food Chemistry*, 2000; 68: 359-367.
25. Kalpanadevi V. & Mohan R. V. Nutritional and anti nutritional assessment of under utilized legume *D. lablab* var. *vugaris* L. *Bangladesh Journal of Scientific and industrial research*, 2013; 48(2): 119-130.
26. Makinde F.M. & Akinoso R. Nutrient composition and effect of processing treatments on anti-nutritional factors of Nigerian sesame (*Sesamum indicum* Linn) cultivars. *International Food Research Journal*, 2013; 20(5): 2293-2300.
27. Mandizvo T. & Odindo O. A. Seed mineral reserves and vigour of Bambara groundnut (*Vigna subterranea* L.) landraces differing in seed coat colour. *Heliyon*, 2019; 5: 1-10.
28. Martinez-Herrera J., Siddhuraju P., Francis G., Davila-Ortiz G. & Becker K. Chemical composition and effects of different treatment on the levels, in four provenances of *Jatropha curcas* L. from Mexico. *Food Chemistry*, 2006; 96(1): 80-89.
29. Mauron J. Protein in Human Nutrition. Eds Rod, J.W.G. and Rolls B.A. Academic Press, New York, 1973; 1-2.
30. Mazahib A.M., Nuha M.O., Salawa I.S. & Babiker E.E. Some nutritional attributes of bambara groundnut as influenced by domestic processing. *International Food Research Journal*, 2013; 20(3): 1165-1171.
31. Mbougueng P. D. Influence des amidons natifs ou acétylés de manioc et de pomme de terre sur les propriétés physico-chimiques et texturales du paté de bœuf (*Bos indicus*). Thèse de doctorat. Institut National Polytechnique de Lorraine, Nancy, France, 2009; 172.
32. Mebdoua S. Caractérisation physico-chimique de quelques populations de niébé (*Vigna unguiculata* L. Walp.) : influence des traitements technologiques. Mémoire de Magister en Phytotechnie (Amélioration de Production Végétale et Ressources Génétiques), Ecole Nationale Supérieure Agronomique, Alger, Algérie, 2011; 82.
33. Motta C., Matos A. S., Soares A., Gonzales G. B., Castanheira I., Cabral I., Tavares N. & Nicolai M. Amino acid profile of foods from the Portuguese total diet pilot study. *Journal of Food Composition and Analyses*, 2020; 92: 1-36.
34. N'guetta A. M. N. Caractéristiques agro morphologiques, nutritionnelles des cultivars de *Citrullus lanatus* (Cucurbitaceae) cultivés en Côte d'Ivoire et utilisation de leurs tourteaux en production de poulets de chair (*Gallus gallus*). Thèse pour le titre de Docteur en Biochimie et Technologie des Aliments de l'Université Nangui Abrogoua, Abidjan, Côte d'Ivoire, 2016; 260.
35. Nwofia G. E., Ojimelukwe P. & Eji C. Chemical composition of leaves, fruit pulp and seeds in some Carica papaya (L.) morphotipes. *International Journal of Medecine and Aromatic Plants*, 2012; 2(1): 200-206.
36. Oyeyinka B. O. & Afolayan A. J. Comparative evaluation of the nutritive, mineral, and antinutritive composition of *Musa sinensis* L. (Banana) and *Musa paradisiaca* L. (Planain) fruit compartments. *Plants*, 2019; 8(12): 1-14.

37. Picaud C. Oligo-éléments : excès, carences et Conseil officinal. Thèse de Doctorat, Faculté de Pharmacie, Université de Limoges, Limoges, France, 2017; 143.
38. Rémond D. & Walrand S. Les graines de légumineuses: caractéristiques nutritionnelles et effets sur la santé. Innovations Agronomiques, 2017; 60: 133-144.
39. Sadler G.D. & Murphy P. A. pH and titratable acidity chapter. In: Food analysis, 4 Edition, SS Nielsen (ed), springer, New York, United States of America, 2010; 219-238.
40. Saulais C., Calcium et magnésium dans l'organisme humain: Trois sites d'action comparés. Thèse de Doctorat, Faculté de Pharmacie, Université Henri Poincaré, Nancy I, France, 2000; 114.
41. Sengev A. I., Abu J. O. & Gernah D. I. Effect of Moringa oleifera leaf powder supplementation on some quality characteristics of wheat bread. *Food and Nutrition Sciences*, 2013; 4: 270–275.
42. Shrestha K. A. & Noomhorm A. Comparison of physico-chemical properties of biscuits supplemented with soy and kinema flours. *International Journal of Food Science and Technology*, 2002; 37: 361-368.
43. Skalli-Pariat A. Minéraux et oligo-éléments: indications et propriétés, 2017; 28.
44. Taylor M. Nerve impulse conduction and electrical conduction. Rothwell Press: London, 2003; 245.
45. Tchumou M., Yapi G. & Wohi M. Graines de haricot sec (*Phaseolus lunatus*) consommées au Sud-Est de la Côte d'Ivoire : une alternative dans la lutte préventive des maladies cardiovasculaires, le diabète de type 2. *International Journal of Scientific & Engineering Research*, 2019; 10(12): 340-352.
46. Touati-Mecheri D., Statut nutritionnel et sociodémographique d'une cohorte de femmes enceintes d'El Khroub (Constantine, Algérie). Répercussions sur le poids de naissance du nouveau-né. Thèse de Doctorat de l'Université Mentouri de Constantine, Constantine, Algérie, 2002; 188.
47. Yao A. K., Koffi D. M., Blei S. H., Irie Z. B. & Niamke S. L. Propriétés biochimiques et organoleptiques de trois mets traditionnels ivoiriens (attiéké, placali, attoukpou) à base de granulés de manioc natifs. *International Journal of Biological and Chemical Sciences*, 2015; 9(3): 1341-1353.