

# Search for local food supplements: Study of the nutritional value of 15 plant species from Niger.

## ABSTRACT

In Niger, the prevalence of malnutrition and mortality linked to undernutrition among Nigerien children under 5 years of age still remains high and constitutes a major concern for public authorities. However, the country is teeming with significant biodiversity that could help combat high levels of undernutrition among children aged 6 to 59 months. The present study aims to evaluate the nutritional quality of 15 plant species from which 17 samples were taken, as potential complementary foods, using the methods of the Association of Official Analytical Chemists (1984, 1990, 1995). The water, ash, lipids, proteins and cellulose contents were determined. Carbohydrate content and energy density were calculated. Biochemical characterization of sampled foods shows that *glycine max seeds* are richer in protein (36.39%). The *Neocarya macrophylla* almond has relatively high contents of lipids (60.75%) and celluloses (26.74%). The pulp of *Hyphaene thebaica* is richer in mineral elements (7.16%). The tuber of *Ipomoea batatas* (95.25%) and the pulp of *Neocarya macrophylla* (93.01%) contain sufficient carbohydrates and the humidity is found to be higher specifically in the cereal (*Pennisetum glaucum*) and the tuber of *Borassus aethiopum* with respective rates of 6.72% and 5.70%. In addition, a positive and significant correlation was observed on the one hand between the cellulose content and that of proteins and lipids and on the other hand between the protein level and the lipid level. On the other hand, the correlation between the level of carbohydrates and those of proteins and lipids is negative and very significant. The results confirm that the pulps and kernels of fruits, legumes, tubers and cereals can be incorporated into numerous preparations intended for children to supplement their diet.

**Keywords:** Local food products, Nutrition, Food supplement, Niger

## 1. INTRODUCTION

In the Sahel, drought constitutes the main risk affecting agrosylvopastoral production through reductions in food production, in the number of animals and their productivity, in agricultural income, with the consequence of food insecurity, even food crises and nutritional [1] . Indeed, in developing countries, intakes are more monotonous in their composition, with diets lacking diversity. The degree of economic development and income level have important implications for the types of food that can be produced to satisfy human needs [2] . Thus, food prices and the country's economy are factors that influence human nutrition [3] . The Sahel is marked by a high prevalence of malnutrition and mortality linked to undernourishment among children under 5 years old. The causes of malnutrition are multifactorial. They can result from inadequate food intake, diseases, household food insecurity, access to health services, inappropriate care practices, access to drinking water, poor living conditions. hygiene [4] .

In Niger, malnutrition, particularly undernutrition and micronutrient deficiencies, persists and constitutes a public health problem [5] . Thus, the prevalence of global acute malnutrition (GAM) among children aged 6 to 59 months, severe acute malnutrition and chronic malnutrition (stunting) is estimated, respectively, at 12.2% (well above above the WHO safety threshold of 10%), 2.4% and 47.0% [6] . Factors associated with chronic malnutrition were children's age, sex, birth order, mothers' educational level, diarrhea, fever, acute respiratory infection and anemia [7] .

In addition, on a practical level, complementary feeding is introduced in a timely manner in 8 out of ten cases (80.6%) but less than half of the children (47%) receive breast milk until the age two years. The diet of children aged 6-23 months is generally poorly diversified (the minimum dietary diversity rate is 8.7%), mainly based on starchy foods (91.1%), followed by the group of legumes and nuts (29 .6%), fruits and vegetables rich in vitamin A (25.6%) in addition to breast milk (85.6%). Therefore, the prevalence of overall anemia (mild, moderate and severe) in children aged 6 to 59 months is high and stands at 55.5% [6] .

The issue of nutrition is seen today as a global concern, characterized by a real collective awareness expressed within the Scaling Up Nutrition (SUN) Movement which brings together 60 countries in 2017 [4] . One of the most promising solutions to sustainably combat malnutrition is to design programs that will take into account locally produced foods [8] . Dietary approaches constitute levers that can significantly contribute to reducing the prevalence of malnutrition (Houndji et al 2013). For example, daily

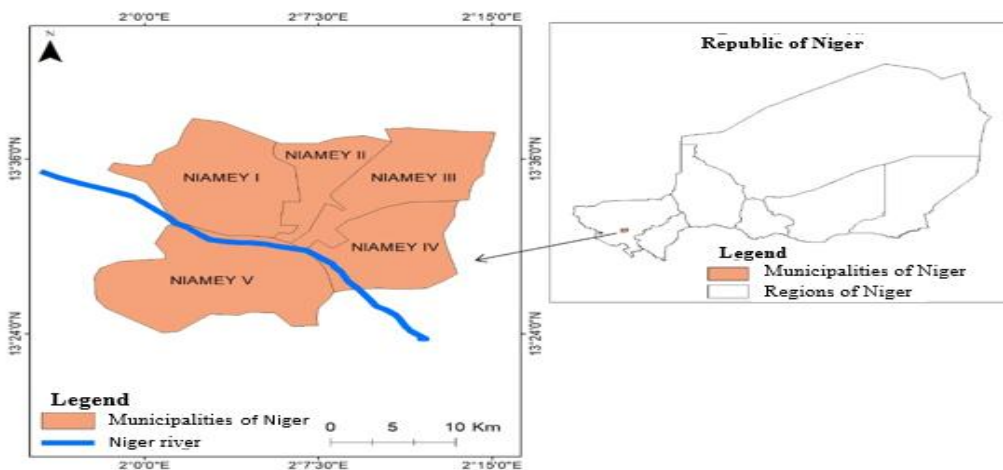
supplementation with moringa leaf powder significantly improves the nutritional status of children for wasting, stunted growth and underweight [9] .

From the age of six months, breast milk intake becomes insufficient to meet the needs of infants and young children and must be supplemented by a diversified and high nutritional density so-called “complementary” diet [10] . The present research aims to evaluate the nutritional quality of 15 plant species from which 17 samples were taken, as potential complementary foods .

## 2. MATERIALS AND METHODS

### 2.1. Presentation of the study area

The urban commune of Niamey (Niger) served as the study setting. It is made up of five (5) municipal districts. The population of Niamey is estimated at approximately 1,492,414 inhabitants [11] . The average rainfall and temperature were 539.16 mm and 29.59°C, respectively [12] . In addition, a previous study listed 15 types of porridge used as complementary food among children aged 6 to 24 months in the urban community of Niamey, 6 of which come from industrial flours of known composition and the other 9 which are porridges. local traditions [13] . In this region the continuation of breastfeeding until the age of two years was estimated at 14.9% and the minimum dietary diversity among children aged 6 – 23 months is estimated at 31.1% [6] .



**Figure1: Map of the study area**

## 2.2 . Plant material

It is made up of 15 plant species from which 17 samples were taken. The scientific names of the plant species, the organs used, the vernacular names and the provenances are grouped in Table I. This table shows that 6 samples are used in the grilled form, 8 in the raw form and 3 in the cooked form.

**Table 1: Composition and characteristics of plant material**

Scientific names	Names in French	Local names	Languages <sup>1</sup>	Organs used <sup>2</sup>	Codes	Forms used	Origins
<i>Adansonia digitata</i>	Baobab	kuka, koo nya, bokki,	H, Z, F	Could	Addi	believed	Local market
<i>Arachis hypogaea</i>	Peanut	gujiya, damsi, kolhi,	H, Z, F	Gr	Arhy	grilled	Local market
<i>Glycine max</i>	Soy		H, Z, F	Gr	Glma	grid	Local market
<i>Ziziphus mauritiana</i>	Jujube	magaria, darey, djâbhi,	H, Z, F	Am	ZimaA	believed	Local market
<i>Western Anacardium</i>	Cashew	Say tourizé	Z	Am	Anoc	grid	Local market
<i>Borassus aethiopum</i>	Rônier	jijinia, bê, dubbhy	H, Z, F	You	Boae	cooked	Local market
<i>Parkia biglobosa</i>	Nere	dorowa, dosso, nareehi,	H, Z, F	Could	Pabi	believed	Local market
<i>Cucurbita SP.</i>	Squash	kankana, laptanda, faireare.	H, Z, F	Gr	Cusp	believed	Local market
<i>vigna unguiculata</i>	Cowpea	wake, dunguri, yanpu,	H, Z, F	Gr	Viun	cooked	Local market
<i>Neocarya macrophylla</i>	cayor apple tree	gawasa, gamsa, nawudi,	H, Z, F	Could	NemaF	believed	Local market
<i>Neocarya macrophylla</i>	cayor apple tree	gawasa, gamsa, nawudi,	H, Z, F	Am	NemaA	believed	Local market
<i>Sesamum indicum</i>	Sesame	lamti, lamti,	H, Z, F	Gr	Breast	grid	Local market

<i>Ipomoea batatas</i>	Yam	dankaly, kudaku, dagafibre,	H, Z, F	You	Ipba	cooked	Local market
<i>Sclerocarya birrea</i>	Marula	daniya, diney (luley), hedi,	H, Z, F	Am	Scbi	grid	Local market
<i>Pennisetum glaucum</i>	Mil	hatsi;hayni;gawuri	H, Z, F	Gr	Pegl	grid	Niamey
<i>Hyphaene thebaica</i>	Doum Palm	goriba, kangaunya, gellehy,	H, Z, F	Could	Hyth	believed	Local market
<i>Ziziphus mauritiana</i>	Jujube	magaria, darey, djâbhi,	H, Z, F	Could	ZimaF	believed	Local market

1: H=Hausa; Z=Zarma; F=Fulfulde. 2: Am = Almond; Pu= Pulp; Gr = Grain e ; You=Tuber. **Source:** [14] .

UNDER PEER REVIEW

## 2.3 . Methodology for determining biochemical parameters

The methodology used during this study is diversified depending on the biochemical parameter studied.

### 2.3.1. Water content

The method used for determining the water content was that proposed by the AOAC [15] . It consists of carrying out differential weighing of the crucibles, containing 5g of sample, before and after passing through the oven at 105°C. The difference in weights before and after drying made it possible to determine the humidity.

$$W(\%) = \frac{m_e - m_s}{m_e} \times 100$$

With :

W: water content in percentage

$m_e$  : mass of the sample before drying in g

$m_s$  : mass of the sample after drying in g

### 2.3.2. Ash content

The method used to determine ash contents was described by AOAC (1990). Thus, in a crucible, two (2) grams of the ground material were incinerated at 550°C for 6 hours in a NABERTERM brand muffle furnace, MORE THAN HEAT 30-3000oC, Germany. After cooling in a desiccator, it was weighed again. The ash content was expressed as a mass percentage.

$$C(\%) = \frac{m_2}{m_1} \times 100$$

$m_1$ : mass of test sample in g

$m_2$ : mass of ash in g.

### 2.3.3. Cellulose

The crude fiber content was estimated by the Weende method. This method is carried out in 2 hydrolysis, one acidic with 1.25% H<sub>2</sub>SO<sub>4</sub>, extracts the sugars and starch, and the other alkaline (basic) with 1.25% NaOH, allows the proteins to be extracted. and part of the hemicellulose and lignin. The acid-base

hydrolyses are separated and isolated using filtration and rinsing with hot water [16] . The cellulose content is obtained through the following formula:

$$\text{Cellulose brute (\%)} = \frac{P2 - P3}{P1} \times 100$$

P1: Sample weight;

P2: Weight of the crucible + cellulose + mineral materials;

P3: Weight of the crucible + mineral materials.

#### **2.3.4. Protein content:**

The protein content of the samples was determined by the Kjeldahl method. It consists of using an automatic distiller brand UDK 129. It is done in three phases which are mineralization, distillation and colorimetric dosage (volumetric dosage). The nitrogen and crude protein contents relative to the fresh material are calculated directly and given by the device using 6.25 as a conversion factor [17] .

**2.3.5. Lipid content:**The fat content of foods was determined by the Soxhlet method with gravimetric extraction of lipids. The principle is based on the extraction of a test portion with hexane by percolation. Followed by elimination of the solvent by distillation and finally by drying the residue in an oven and weighing it. Determination of lipids was carried out according to the analytical method [18] .

**2.3.6. Total carbohydrate content:**The total carbohydrate content in relation to dry matter is determined by the differential method (method used at laboratory level). The calculation was made with the determined values of protein, lipid, ash and humidity levels (Garba dit Gado et al., 2019) . The formula used is as follows:

$$\% \text{total carbohydrates/DM} = 100 - [\% \text{Fat} + \% \text{protein} + \% \text{ash}]$$

**2.3.7. Determination of energy density:**Energy density (ED) was calculated according to the equation of Atwater and Benedict [19].

$$DE = (9 \times \text{lipids (g)} + 4 \times \text{proteins (g)} + 4 \times \text{carbohydrates (g)} + 2 \times \text{Cellulose (g)}).$$

#### **21.3.8. Statistical analysis**

The data are processed and analyzed using Minitab version 19, SPSS version 25 and Excel 13 software. Indeed, the comparison of the means of biochemical parameters is carried out according to the Tukey test at the 5% probability threshold. Finally, the hierarchical ascending classification of foods, the comparison of means according to the food category, and the correlation between the different physicochemical variables were carried out with SPSS software.

## 2. RESULTS

### 2.1. Biochemical characterization of foods

#### Proteins, lipids, carbohydrates, ash and moisture from fruit seeds, tubers, pulps and kernels

Table 2 presents the biochemical composition of fruit seeds, tubers, pulps and kernels. It has water contents lower than 7%. Indeed, the highest water content was 6.72% in millet seeds ( *Pennisetum glaucum* ) and the lowest 1.55% ( *Anacardium occidentale* ). Furthermore, the total ash content is higher in the fruit pulp of the doum palm ( *Hyphaene thebaica* ) at 7.16% but lower in the seeds of millet ( *Pennisetum glaucum* ) with a rate of 1.85%. It is clear from this table that legumes and fruit kernels contain the highest levels of protein and lipids. Thus, the highest protein value was observed in soybean ( *Glycine max* ) of 36.39% followed by *Sclerocarya birrea* almond (30.84%) and that of the least was 2.11% in sweet potato ( *Ipomoea batatas* ).

Furthermore, the largest lipid content is 60.75% in *Neocarya macrophylla* kernel and that of the smallest is 0.20% in sweet potato tuber ( *Ipomoea batatas* ). On the other hand, all fruit pulps, tubers, cereals and some legumes contain enough carbohydrates. For this purpose, the sweet potato tuber is exclusively rich in carbohydrates with a rate of 95.25% and the lowest value is obtained in the *Sclerocarya birrea* kernel (6.45%). Regarding the comparison of average moisture, ash, protein, lipid and carbohydrate contents. The difference is not significant within each group.

**Table 2 : Protein, fat, carbohydrate, ash and moisture contents of fruit seeds, tubers, pulps and kernels**

Scientific Names <sup>1</sup>	Proteins (100g/DM)	Fats (100g/DM)	Carbohydrates (/100g /DM)	Ashes (100g/MS)	Humidities (100g)
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<i>Adansonia Digitata</i>	3.11± <sup>0.59g</sup>	0.44±0.20 <sup>hrs</sup>	90.39±2.12 <sup>ab</sup>	6.06± <sup>1.6a</sup>	5.28±0.48 <sup>abc</sup>
<i>Arachis hypogaea</i>	23.76± <sup>1.01c</sup>	38.93±5.68 <sup>d</sup>	34.01± <sup>4.88f</sup>	3.3±0.27 <sup>bcd</sup>	1.69± <sup>0.51g</sup>
<i>glycine max</i>	36.39± <sup>1.83a</sup>	8.54± <sup>0.92f</sup>	51.22±2.74 <sup>e</sup>	3.86±0.04b c	3.46±0.80 <sup>cdefg</sup>
<i>Ziziphus mauritiana</i> <sup>A</sup>	29.40± <sup>0.43b</sup>	29.79± <sup>1.04e</sup>	37.79± <sup>1.09f</sup>	3.02±0.13 bcd	3.85±0.74 <sup>bcdef</sup>
<i>Western Anacardium</i>	21.29±1.37 cds	48.92± <sup>0.40c</sup>	27.60± <sup>2.12g</sup>	2.19± <sup>0.48d</sup>	1.55± <sup>0.77g</sup>
<i>Borassus aethiopum</i>	6.18±1.50 <sup>f</sup>	0.83±0.40 <sup>gh</sup>	91.10±1.75 <sup>ab</sup>	1.89± <sup>0.07d</sup>	5.7±0.50 <sup>ab</sup>
<i>Parkia biglobosa</i>	5.13±0.86 <sup>fg</sup>	0.89±0.24 <sup>gh</sup>	89.71±0.82 <sup>ab</sup>	4.27± <sup>0.17b</sup>	3.17±0.50 <sup>defg</sup>
<i>Cucurbita SP.</i>	29.39±0.61 b	53.71±0.58 <sup>b</sup>	14.03±0.43 <sup>hours</sup>	2.87±0.15 bcd	2.45±0.29 <sup>efg</sup>
<i>Vigna unguiculata</i>	17.82±2.35 d	1.94±0.25 <sup>gh</sup>	77.35± <sup>2.56d</sup>	2.89±0.06 bcd	5.41±0.19 <sup>ab</sup>
<i>Neocarya Macrophylla</i> <sup>F</sup>	3.47±0.04 <sup>fg</sup>	0.71±0.18 <sup>gh</sup>	93.01±1.13 <sup>ab</sup>	2.81±0.91 bcd	5.58±0.99 <sup>bcde</sup>
<i>Neocarya Macrophylla</i> <sup>A</sup>	18.89± <sup>1.48d</sup>	60.75± <sup>0.45a</sup>	18.29±2.24 <sup>hours</sup>	2.07± <sup>0.38d</sup>	2.19±0.22 <sup>fg</sup>
<i>Sesamum indicum</i>	24.01± <sup>0.66c</sup>	60.05± <sup>0.53a</sup>	12.96±0.18 <sup>f</sup>	2.98±0.22 bcd	1.86± <sup>0.30g</sup>
<i>Ipomoea batatas</i>	2.11± <sup>1.11g</sup>	0.20±0.10 <sup>hrs</sup>	95.25± <sup>1.36a</sup>	2.44±0.64 cds	3.17±0.58 <sup>defg</sup>
<i>Sclerocarya birrea</i>	30.84± <sup>1.86a</sup>	58.64± <sup>1.54a</sup>	6.45± <sup>1.28i</sup>	4.07±0.03 <sup>b</sup>	1.76± <sup>0.52g</sup>
<i>Pennisetum glaucum</i>	10.06± <sup>0.90e</sup>	5.17±0.41 <sup>fg</sup>	82.92±1.60 <sup>cds</sup>	1.85±0.38 <sup>d</sup>	6.72± <sup>0.43a</sup>
<i>Hyphaene thebaica</i>	3.66± <sup>1.41g</sup>	0.78±0.14 <sup>gh</sup>	88.41±1.65 <sup>bc</sup>	7.16± <sup>0.15a</sup>	4.43±0.85 <sup>bcd</sup>
<i>Ziziphus mauritiana</i> <sup>F</sup>	4.15±0.40 <sup>g</sup>	0.85±0.39 <sup>gh</sup>	90.87±0.71 <sup>ab</sup>	4.12±0.34b	4.17±1.15ab

1: F=Fruit Pulp and A=Fruit Kernel

The means on a column sharing no letters are significantly different at the 5% threshold

**Cellulose and energy density of seeds, pulp and kernels of fruits and tubers**

Legumes and fruit kernels are extremely rich in cellulose with the exception of *Vigna unguiculata* (Table 3). For this purpose, the highest values were reported by the almond of *Neocarya macrophylla* (26.74%), the seed of *Cucurbita SP* (23.75%), the almond of *Sclerocarya birrea* (18.80%), *Ziziphus mauritiana* almond (17.92%), Western Anacardium almond, seed of *Sesamum indicum* (16.29%). Seed of *Vigna unguiculata* is so low in cellulose (1.48%). Compared to the energy density after calculation, the *Neocarya macrophylla* almond presents the greatest energy value. The energy values of the samples analyzed oscillate between 392.24 and 748.93 Kcal/100g.

**Table 3: Water, ash, cellulose and energy density contents**

Scientific Names <sup>1</sup>	Cellulose (g /100g /MS)	Energy density (Kcal/100g)
<i>Adansonia Digitata</i>	8.10±0.23	394.13
<i>Arachis hypogaea</i>	11.35±0.20	604.13
<i>glycine max</i>	7.84±0.60	442.95
<i>Ziziphus mauritiana</i> <sup>A</sup>	17.92±1.29	572.67
<i>Western Anacardium</i>	16.42±3.48	668.69
<i>Borassus aethiopum</i>	2.82±0.24	402.21
<i>Parkia biglobosa</i>	14.08±1.28	415.52
<i>Cucurbita SP.</i>	23.75±2.19	704.54
<i>Vigna unguiculata</i>	1.48±0.33	401.06
<i>Neocarya Macrophylla</i> <sup>F</sup>	4.68±0.10	401.65
<i>Neocarya Macrophylla</i> <sup>A</sup>	26.74±1.75	748.93
<i>Sesamum indicum</i>	16.29±2.12	720.91
<i>Ipomoea batatas</i>	2.61±0.11	396.43
<i>Sclerocarya birrea</i>	18.80±3.31	714.50
<i>Pennisetum glaucum</i>	2.76±0.25	423.99
<i>Hyphaene thebaica</i>	10.46±0.23	396.18
<i>Ziziphus mauritiana</i> <sup>F</sup>	2.23±0.10	392.24

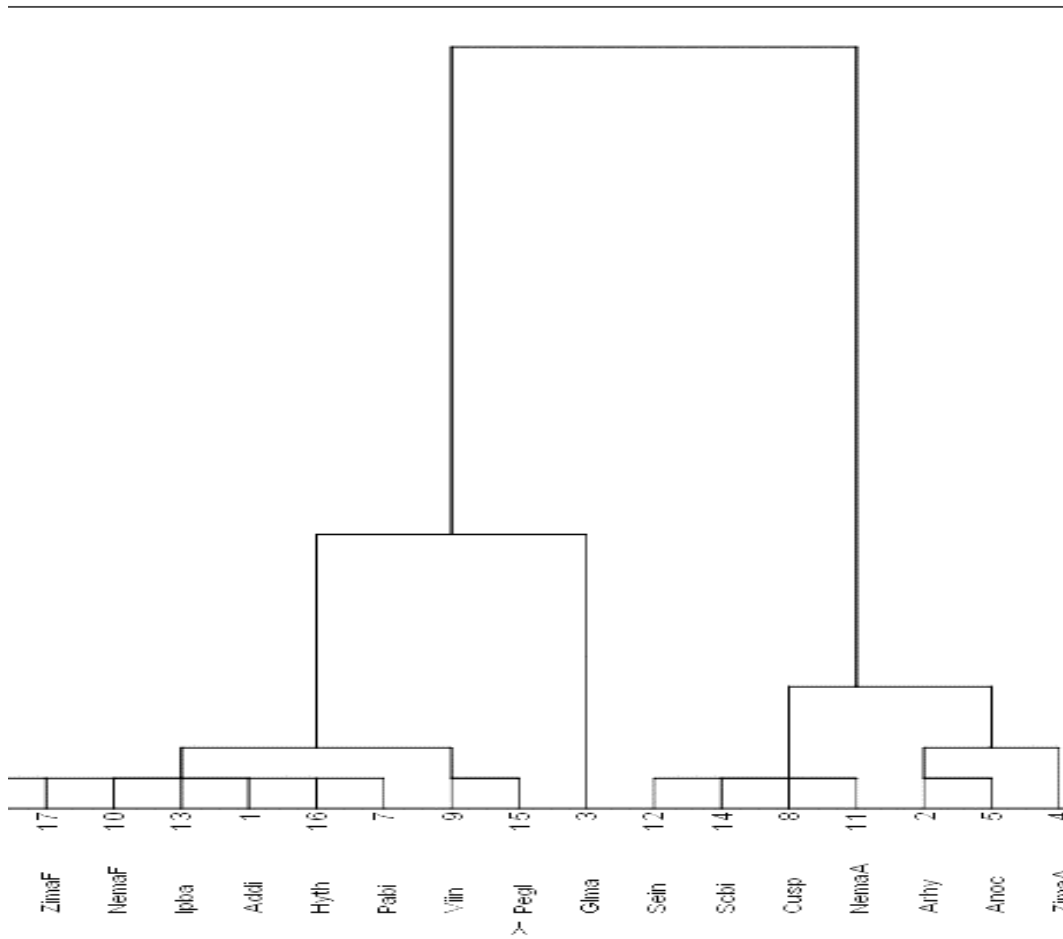
1: F=Fruit Pulp and A=Fruit Kernel

## 2.2. Correlation according to biochemical parameters of fruit seeds, tubers, pulps and kernels

The results of comparisons of the averages of biochemical parameters according to the food category to which the plant species belongs (Table 4), show that legumes are richest in proteins and they are followed by fruit kernels. Fruit almonds have the highest lipid content. They are also the richest in cellulose. Furthermore, the greatest carbohydrate values were observed in the pulp, cereal and tuber categories. Finally, the vast majority of mineral elements are found in fruit pulps.

**Table 4:** Comparison of nutrient content based on food category

Food categories	Proteins	lipids	Carbohydrates	Humidities	Ashes	Cellulose
<b>Pulps</b>	3.90	0.73	90.48	4.53	4.88	7.91
<b>Cereals</b>	10.06	5.17	82.92	6.72	1.85	2.76
<b>Legumes</b>	26.27	32.63	37.91	2.97	3.18	12.14
<b>Almonds</b>	25.11	49.52	22.53	2.34	2.84	19.97
<b>Tubers</b>	4.14	0.51	93.18	4.44	2.17	2.72
<b>Averages</b>	15.86	21.83	58.90	3.67	3.40	11.08



**Figure 2: Ascending Hierarchical Classification of samples**

The ascending hierarchical classification made it possible to identify three different groups:

**-Group 1 :** Composed of foods such as the tubers of the young shoots of *Borassus aethiopum* (Boae) and *Ipomoea batatas* (Ipba) , the fruit pulps of *Ziziphus mauritiana* (ZimaF) , *Neocarya macrophylla* (NemaF) , *Adansonia digitata* (Addi) , *Hyphaene thebaïca* (Hyth) and *Parkia biglobosa* (Pabi), the seeds of *vigna unguiculata* (Viun) and *Pennisetum glaucum* (Pegl). It represents 53% of foods and is characterized by high values of carbohydrates and water .

However, these foods have low values of proteins , lipids and celluloses.

- **Group 2: Composed of foods such as** *Sesamum indicum* ( Breast) legumes and *Cucurbita SP* (Cusp), the fruit kernels of *Sclerocarya birrea* (Scbi) and *Neocarya macrophylla* (NemaA). It represents 29% of the samples and is characterized by high protein values .

-**Group 3:** Composed of foods such as *Arachis hypogaea* (Arhy) and *Western Anacardium*(Anoc) and *Ziziphus mauritiana* (ZimaA). It represents 18% and is characterized by high values of lipids and cellulose but low values of carbohydrates and water.

Table 5 presents the various correlations established between the biochemical measurements. The biochemical parameters from the samples showed positive and significant correlations ( $r = 0.56$ ,  $p = 0.0000$ ;  $r = 0.83$ ,  $p = 0.0000$  and  $r = 0.69$ ) respectively between the cellulose content and the protein and lipid levels, then between the protein level and the lipid level. On the other hand, a negative and very significant correlation ( $r = -0.84$ ,  $p = 0.0000$  and  $r = -0.96$   $p = 0.0000$ ) was observed between the level of carbohydrates and those of proteins and lipids. Likewise, negative and significant correlations ( $r = -0.75$ ,  $p = 0.0000$ ;  $r = -0.68$ ,  $p = 0.0000$ ;  $r = -0.54$ ,  $p = 0000$ ) were observed between the humidity level and the lipid level, between the humidity level and the cellulose level as well as between the protein level and the humidity level.

**Table 5:Correlation between the different physicochemical variables**

		Humidity	Ash	Cellulose	Protein	Lipid	Carbohydrate
<b>Humidity</b>	Correlation	1					
	Sig. (bilateral)						
<b>Ash</b>	Correlation of	0.053	1				
	Sig. (bilateral)	0.71					
<b>Cellulose</b>	Correlation	-0.683**	-0.034	1			
	Sig. (bilateral)	0.000	0.815				

<b>Protein</b>	Correlation	-0.542**	-0.214	0.565**	1		
	Sig. (bilateral)	0.000	0.132	0.000			
<b>Lipid</b>	Correlation	-0.751**	-0.278*	0.837**	0.693**	1	
	Sig. (bilateral)	0.000	0.048	0.000	0.000		
<b>Carbohydrate</b>	Correlation	0.741**	0.236	-0.814**	-0.848**	-0.968**	1
	Sig. (bilateral)	0.000	0.095	0.000	0.000	0.000	

\*\* The correlation is significant at the 0.01 level (two-tailed).

\* The correlation is significant at the 0.05 level (two-tailed).

### 3. DISCUSSION

Niger has plant species which provide numerous products which are used by the population in general and in rural areas in particular. The food use of the latter mainly concerned fruits, pulps, leaves, flowers, seeds and almonds [20]. The present study concerned 15 local plant species from which 17 samples distributed as follows: 4 fruit pulps, 4 fruit almonds, 6 seeds, 2 tubers. Biochemical analyzes of all of these samples showed very variable contents of proteins, lipids, carbohydrates, cellulose, moisture, and ash (mineral elements) which often vary depending on the plant species, food group and of the part concerned (fruit or almond). It is important to note that all data were reported on a dry matter basis. Most of the previous studies encountered are more interested in raw fibers (total fibers) than cellulose, as well as the different types of minerals and ash contents, hence these points will be less compared with literature data.

#### 3.1. Moisture, ash, proteins, lipids and carbohydrates

The biochemical characterization of fruit seeds, tubers, pulps and kernels presented water contents lower than 7%. This low content observed allows their better conservation [21]. These rates are lower than those reported in Togo on seeds which was 9% [8]. Indeed, in this study the highest water content was 6.72% in millet seeds (*Pennisetum glaucum*). It was 5.28% in the pulp of *Adansonia digitata*, 2.45% in the seeds of *Cucurbita SP* and 1.55% in the kernel of *Western Anacardium* which was the lowest value. These values differ from those of another study carried out in Niger on two species of Cucurbitaceae (*Citrullus Colocynthis* and *Lagenaria siceraria*) whose water contents varied from 7 to 9.50% [22]. The

baobab pulp was characterized by a water content which is close to that found by other authors which varied from 6 to 15% [23] . In addition, baobab pulp is characterized by prebiotic potential. Indeed, fermentation of baobab pulp powder presented characteristics of selective utilization by host microorganisms [24] . The highest total ash contents were observed in the pulps of *Hyphaene thebaïca*, *Adansonia digitata*, *Parkia biglobosa*, *Ziziphus mauritiana* with respective values of 7.16%, 6.06%, 4.27%, 4.12% and that of the lowest in millet seeds ( *Pennisetum glaucum* ) of 1.85%. A high total ash content was mentioned for baobab pulps which was 9.7% (Ayosso et al., 2015) .

It appears from this present study that legumes and fruit kernels contain the highest levels of protein and lipids. Thus, the highest protein value was observed in soybean ( *Glycine max* ) at 36.39% followed by *Sclerocarya birrea* almond (30.84%) and that of the least was 2.11% in sweet potato (*Ipomoea batatas*). The results obtained are approximately similar to those found on soy varieties consumed in Burkina Fasso and Togo with respective protein contents of 31.04% and 34.43% [8,26] . According to a previous study in Niger, the kernels of *S. birrea* fruits constitute a great potential and a very rich composition, reporting contents which varied depending on the origin from 31.1 to 39.9% of proteins [27] . It is a very fruitful plant, the number of fruits per tree varies from 136 to 4256 with an average fruit weight and diameter of 12.66 and 26.71 mm respectively and the number of almonds varies from 1 to 3 per fruit [28] .

The highest lipid contents were obtained in the kernels of *Neocarya macrophylla* , *Sclerocarya birrea* , and *Anacardium occidentale* , the seeds of *Sesamum indicum* and *Cucurbita* , respectively 60.75%, 58.64%, 48.92%, 60.05% and 53.71%. These values are high compared to those of the *Ipomoea tuberbata* , fruit pulps of *Adansonia digitata* which are 0.20% and 0.44% respectively. A previous study in Niger noted a higher fat content of 67.5% for the almond *Neocarya macrophylla*[29] . The variations observed could be linked to the degree of maturity, genetic influence, temperature, sunshine, nature of the soil. The results of another previous study on the almond of this plant showed that the oil contained myristic acid, palmitic acid, stearic acid, palmitoleic acid, elaidic acid, oleic acid, erucic acid, behenic acid, heneicosanoic acid, icosatetraenoate and eicosatrienoic acid [30,31] . Taking into account its nutritional virtues, this plant species must be subject to sustainable management because *N. macrophylla* is mainly renewed by sowing (87.6%), and only slightly by stump shoots (11.1%) [32] . Work carried out on *Sclerocarya birrea* almonds in Niger reported contents which varied depending on the origin from 38 to 56.3% fat, 4.58 to

22.5% carbohydrates, 3.60 to 4, 58% ash [27] . Others have shown variability in nutritional characteristics between provenances of *Western Anacardium* . Thus, the highest fat values were noted in nuts from Ziguinchor (54%) followed by those from Sédhiou (44%) and Kolda (37%) [33] . In addition, studies have found similar lipid levels of *Sesamum indicum* of 60.05%, 61.70%, 52.4 to 62.8%, 49.83% to 59.85%, respectively [34–36] .

The present study also shows that all fruit pulps, tubers, cereals and some legumes contain sufficient carbohydrates. Indeed, the tubers of sweet potato ( *Ipomoea batatas* ) and the young shoot of *Borassus aethiopicum* , the fruit pulps of *Neocarya macrophylla* , *Ziziphus mauritiana* and *Adansonia digitata* are exclusively rich in carbohydrates with respective levels of 95.25%, 91 .1%, 93.01%, 90.87%, 90.39% and the lowest value is obtained in the kernel of *Sclerocarya birrea* (6.45%). In Burkina Faso, a very similar study on the tuber of *Borassus aethiopicum* found a similar carbohydrate content of 86.75% [37] . On the other hand, different results were reported from the fruit pulp of *Ziziphus mauritiana* which was 13.05% [38] . This difference could be justified by the methodology used during the determination of the carbohydrate content (spectrophotometric assay). As with *Adansonia digitata* fruit pulp , different results were reported in Benin 73.12% [39] . This difference in carbohydrate content could be due to the differential method used during the operation as it inserted the cellulose content.

### **3.2. Celluloses and energy density**

It appears from Table 3 that legumes and fruit kernels are extremely rich in cellulose with the exception of *Vigna unguiculata* . Thus, the greatest values were reported by the *Neocarya macrophylla* kernel (26.74%) . , the seed of *Cucurbita SP* (23.75%), the almond of *Sclerocarya birrea* (18.80%), the almond of *Ziziphus mauritiana* (17.92%), the almond of *Anacardium ouest* , the seed of *Sesamum indicum* (16.29%) and the seed *Vigna unguiculata* is so poor in cellulose (1.48%). Previous studies have noted different cellulose results for *Western Anacardium* which varied according to provenance including Kolda (14%), Ziguinchor (13.5%) and Sédhiou (9%) [33] .

Compared to the energy density after calculation, the *Neocarya macrophylla* almond has the highest energy value. The energy values of the samples analyzed oscillate between 392.24 and 748.93 Kcal/100g. This energy richness of fruit almonds and certain legumes could be linked to their high fat

content. [8] reported energy values lower than those of this study in the seeds of two legumes *Arachis hypogaea* and *Sesamum indicum* of 576.08 Kcal and 500.29 Kcal respectively. This difference could be explained by climatic factors and also the difference in methodology used to determine carbohydrate levels.

### **3.3. Correlation according to biochemical and physicochemical parameters of seeds, tubers, pulps and fruit kernels**

The results of comparison of the averages of the biochemical parameters according to the food category to which the plant species belongs (Table 5), show that legumes represent a highest average protein content of 26.27% which is a rate very close to that of fruit almonds of 25.49%. This could mean that, whether or not legumes are available, fruit kernels can be used for their important role in the development, maintenance and repair of tissues. In addition, fruit almonds have the highest lipid content with a rate of 49.52% followed by legumes with a rate of 32.63%. However, the fat content varies, not only depending on the species, but also on the part of the fruit studied (pulp or kernel) [40] .

In addition, the highest carbohydrate values were observed in the pulp, cereal and tuber categories with respective rates of 90.48%, 82.92% and 93.18%. Almonds are also the richest in cellulose with a content of 19.97%, followed by legumes with a rate of 12.14%. As for mineral elements, the largest majority is found in fruit pulps with a content of 4.88% and legumes come in second position with a value of 3.18%. Regarding water contents, the highest content is observed in cereals of 6.72%, followed by pulps with a rate of 4.53% which is practically the same for tubers. It emerges from the analysis of this table that all categories of food which are rich in proteins and lipids have an inverse relationship with the quantity of water. Indeed, the foods with the greatest quantities of proteins and lipids are the poorest in water. These results are different from those found in research work in Algeria for which all the energy-rich fruits studied were in an inverse relationship with the quantity of water, fruits with a high energy content were the poorest in water [40] . This observation is statically confirmed in Table 5 with negative and significant correlations at the 0.01 level ( $r = -0.75, p=0.0000$ ;  $r = -0.68, p= 0.0000$ ;  $r= - 0.54, p=0000$ ) which were observed between the humidity level and the lipid level, as well as between the humidity level and the cellulose level, as well as between the protein level and the lipid level. humidity.

The hierarchical ascending classification of the samples revealed three large groups according to their nutritional composition (Figure 2). The analysis of this figure shows that the first group presents 53% of the samples and mainly consists of fruit pulps and starchy foods (tubers) (Boae, ZimaF, NemaF, Ipba, Addi, Hyth, Pabi, Viin and Pegl). The discriminating criterion is the richness of fruit pulps, starches and *Vigna unguiculata* in carbohydrates and water. The second group constitutes 29% namely Seal Scbi, Cusp, and Nema. The characterizing criterion of this group is the high protein value. Finally, the third group concerns 18% of the samples studied which are Arhy, Anoc, ZimaA. It is mainly characterized by high values of lipids and cellulose but low values of carbohydrates and water.

## Conclusion

At the end of this work we note that the plant species studied present remarkable potential from a nutritional point of view. Plant proteins are present in greater quantities in all almonds and legumes (36.39% for *glycine max* ) which can be used in different areas: human food, livestock feed. The oils of fruit kernels and oilseed legumes are present in appreciable quantities, including 60.75% in the *Neocarya macrophylla kernel* and can have food uses. Pulps, tubers and cereals showed a significant energy contribution.

All parts of the plants analyzed are already used in food in Niger, it would be possible to consider different transformations as flour and to incorporate it into different food products either as food supplements or as raw material.

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