

# 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 ~~Nigerian~~ Nigerian 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 ~~aimed~~ 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 ~~the~~ sampled foods ~~showed~~ shows that *Glycine* max seeds ~~were~~ are richer in protein (36.39%). ~~The~~ *Neocarya macrophylla* almond has a relatively high ~~lipid content~~ contents of lipids (60.75%) and ~~cellulose content~~ celluloses (26.74%). The pulp of *Hyphaene thebaica* ~~was~~ is rich in mineral elements (7.16%). The tuber of *Ipomoea batatas* (95.25%) and the pulp of *Neocarya macrophylla* (93.01%) ~~contained~~ contain sufficient carbohydrates, and the humidity ~~was~~ is found to be higher specifically in the cereal (*Pennisetum glaucum*) and the tuber of *Borassus aethiopum* with ~~rates of 6.72% and 5.70 %, respectively~~ 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 ~~levels~~ level. ~~In contrast~~ ~~On the other hand~~, the correlation between ~~carbohydrate~~ the levels level of carbohydrates and those of proteins and lipids ~~was~~ 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 ~~is~~ constitutes the main risk affecting agrosilvopastoral production through reductions in food production, in the number of animals and their productivity, ~~and~~ in agricultural income, with the consequence of food insecurity, ~~even~~ food crises, and ~~nutrition~~ nutritional [1]. Indeed, in developing countries, ~~intake is~~ ~~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 ~~at~~ the country's economy are factors that influence human nutrition [3]. The Sahel is ~~characterized~~ ~~marked~~ by a high prevalence of malnutrition and mortality linked to undernourishment among children under 5 years ~~of age~~ ~~old~~. The causes of malnutrition are ~~multiple factors~~ ~~multifactorial~~. ~~This~~ ~~They~~ can result from inadequate food intake, diseases, household food insecurity, access to health services, inappropriate care practices, access to drinking water, ~~and~~ 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 ~~are~~ ~~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 ~~wasis~~ introduced in a timely manner in 8 out of ten cases (80.6%), but less than half of the children (47%) ~~received~~ ~~receive~~ breast milk until the age ~~of~~ two years. The diet of children aged 6- ~~to~~ 23 months ~~wasis~~ generally poorly diversified (the minimum dietary diversity rate ~~wasis~~ 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%), ~~and 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 ~~brought~~ ~~brings~~ together 60 countries in 2017 [4]. One of the most promising solutions to ~~combat malnutrition sustainably~~ ~~sustainably~~ ~~combat~~

malnutrition is to design programs that ~~consider will take into account~~ locally produced foods [8]. Dietary approaches constitute ~~levels levers~~ that can significantly contribute to reducing the prevalence of malnutrition (Houndji et al 2013)[9]???. For example, daily supplementation with moringa leaf powder significantly improves the nutritional status of children ~~in terms of~~ wasting, stunted growth, and underweight [9].

From the age of six months, breast milk intake ~~is 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 ~~study research aimed aims~~ to evaluate the nutritional quality of 15 plant species, from which 17 samples were ~~collected 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 ~~site setting~~. It ~~comprises is made up of~~ five (5) municipal districts (Figure 1). The population of Niamey is estimated ~~to be 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, ~~six 6~~ of which come from industrial flours of known composition and the other ~~nine 9 which~~ are porridges. ~~Local 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 ~~was estimated to be is estimated at~~ 31.1% [6].

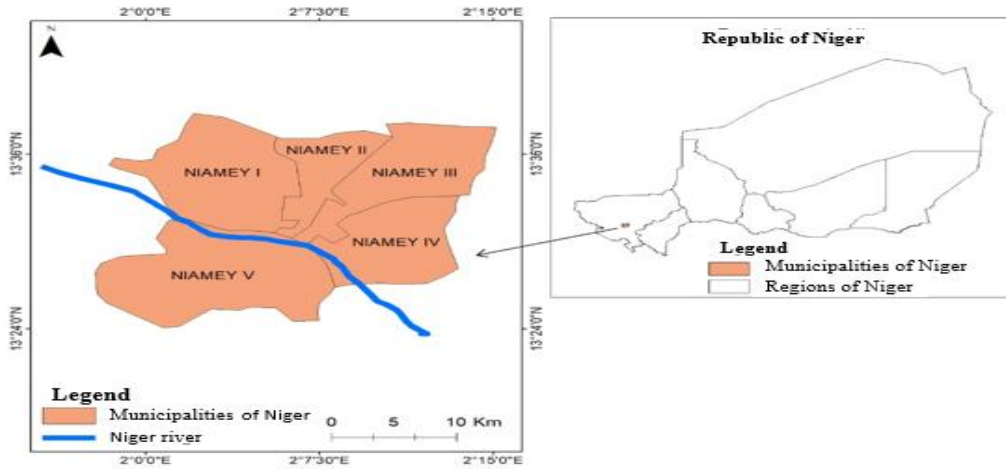


Figure1: Map of the study area **This Figure can be excluded.**

UNDER PEER REVIEW

## 2.2 . Plant material

It ~~was~~ made up of 15 plant species, from which 17 samples were ~~collected~~ taken. The scientific names of the plant species, ~~the~~ organs used, ~~the~~ vernacular names, and ~~the~~ provenances are ~~listed~~ grouped in Table 1. This table shows that ~~six~~ 6 samples ~~were~~ are used in the grilled form, ~~eight~~ 8 in the raw form, and ~~three~~ 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].

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## 2.3 . Methodology for determining biochemical parameters

The methodology used ~~induring~~ this study ~~variedis—diversified~~ depending on the biochemical ~~parametersparameter~~ studied.

### 2.3.1. Water content

The method used for determining ~~the~~ water content was ~~that~~ proposed by ~~the~~ AOAC [15]. It ~~consisted~~ 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, according to Equation 1. **All equations referred to in the text should be numbered serially at the right-hand side in parentheses.**

$$W(\%) = \frac{m_e - m_s}{m_e} \times 100 \quad (1)$$

~~With:~~

W: water content in percentage (%)

~~m<sub>e</sub>~~: mass of the sample before drying ~~in (g)~~

~~m<sub>s</sub>~~: mass of the sample after drying ~~in (g)~~

### 2.3.2. Ash content

The method used to determine ash ~~contenteentents~~ was described by AOAC (1990). Thus, in a crucible, ~~two (2)2~~ grams of the ground material ~~waswere~~ incinerated at 550°C for 6 ~~hhours~~ in a NABER TERM brand muffle furnace, MORE THAN HEAT 30-~~3000eC~~3000°C, Germany. After cooling in a desiccator, ~~the samples wereit wasreweighedweighed again~~. The ash content was expressed as ~~a~~ mass percentage. **All equations referred to in the text should be numbered serially at the right-hand side in parentheses.**

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

~~m<sub>1</sub>~~: mass of test sample ~~in (g)~~

~~m<sub>2</sub>~~: mass of ash ~~in (g)~~.

### 2.3.3. Cellulose

The crude fiber content was estimated ~~using~~ by the Weende method. This method is carried out in ~~two~~ hydrolysis ~~processes~~, one acidic with 1.25% H<sub>2</sub>SO<sub>4</sub>, ~~which~~ extracts the sugars and starch, and the other alkaline (basic) with 1.25% NaOH, ~~allowing~~ allows the proteins to be extracted. and part of ~~the~~ hemicellulose and lignin. ~~Acid-base~~ The ~~acid-base~~ hydrolyses are separated and isolated ~~by~~ using filtration and rinsing with hot water [16]. ~~Cellulose~~ The ~~cellulose~~ content ~~was calculated using~~ is obtained through the following formula: **All equations referred to in the text should be numbered serially at the right-hand side in parentheses.**

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

P1: Sample weight;

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

P3: Weight of ~~the~~ crucible ~~and~~+ 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 ~~performed~~ done in three phases: ~~which are~~ mineralization, distillation, and colorimetric dosage (volumetric dosage). The nitrogen and crude protein contents relative to the fresh material ~~were~~ are calculated directly and ~~provided~~ given by the device using 6.25 as a conversion factor [17].

**2.3.5. Lipid content:** The fat content of ~~the~~ 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~~ the solvent ~~was removed~~ by distillation, and finally by drying the residue ~~was dried~~ in an oven and ~~weighed~~ 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 ~~was~~ is determined ~~using~~ by the differential method (method used at ~~the~~ laboratory level). The calculation was ~~performed using~~ made with the determined values of protein, lipid, ash, and humidity ~~levels~~ (Garba dit Gado et al., 2019). The formula used ~~was~~ is as follows:

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

**2.3.7. Determination of energy density:** The 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 were processed and analyzed using Minitab version 19, SPSS version 25, and Excel 13 software. The comparison of the means of biochemical parameters was carried out according to Tukey's 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 using 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 the fruit seeds, tubers, pulps, and kernels. It has a water content of less than 7%. The highest water content was 6.72% in millet seeds (*Pennisetum glaucum*) and the lowest was 1.55% (*Anacardium occidentale*). Furthermore, the total ash content was higher in the fruit pulp of the doum palm (*Hyphaene thebaica*) at 7.16% but lower in the seeds of millet (*Pennisetum glaucum*) at a rate of 1.85%. It is clear from this table that legumes and fruit kernels contained the highest levels of proteins and lipids. Thus, the highest protein content was observed in soybean (*Glycine max*) at 36.39%, followed by *Sclerocarya birrea* almond (30.84%), and the lowest was 2.11% in sweet potato (*Ipomoea batatas*).

Furthermore, the highest lipid content was 60.75% in *Neocarya macrophylla* kernel and that of the smallest is 0.20% in sweet potato tuber (*Ipomoea batatas*). In contrast, all fruit pulps, tubers, cereals, and some legumes contained sufficient carbohydrates. For this purpose, the sweet potato tuber was exclusively rich in carbohydrates at a rate of 95.25%, and the lowest value was obtained in the *Sclerocarya birrea* kernel (6.45%). Regarding the comparison of

average moisture, ash, protein, lipid, and carbohydrate content was compared contents. These differences difference were is not significant within each group.

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

Scientific Names <sup>1</sup>	Proteins (100g/DM)	Fats (100g/DM)	Carbohydrates (/100g /DM)	Ashes (100g/MS)	Humidities (100g)
<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>	<b>1.69±<sup>0.51g</sup></b>
<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 <sup>c</sup>	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 <sup>bcd</sup>	3.85±0.74 <sup>bcdef</sup>
<i>Western Anacardium</i>	21.29±1.37 <sup>cds</sup>	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 <sup>b</sup>	53.71±0.58 <sup>b</sup>	14.03±0.43 <sup>hours</sup>	2.87±0.15 <sup>bcd</sup>	2.45±0.29 <sup>efg</sup>
<i>Vigna unguiculata</i>	17.82±2.35 <sup>d</sup>	1.94±0.25 <sup>gh</sup>	77.35± <sup>2.56d</sup>	2.89±0.06 <sup>bcd</sup>	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 <sup>bcd</sup>	5.58±0.99 <sup>bcde</sup>
<i>Neocarya Macrophylla</i> <sup>A</sup>	<b>18.89±<sup>1.48d</sup></b>	<b>60.75±<sup>0.45a</sup></b>	18.29±2.24 <sup>hours</sup>	<b>2.07±<sup>0.38d</sup></b>	2.19±0.22 <sup>fg</sup>
<i>Sesamum indicum</i>	<b>24.01±<sup>0.66c</sup></b>	<b>60.05±<sup>0.53a</sup></b>	12.96±0.18 <sup>f</sup>	2.98±0.22 <sup>bcd</sup>	<b>1.86±<sup>0.30g</sup></b>
<i>Ipomoea batatas</i>	<b>2.11±<sup>1.11g</sup></b>	<b>0.20±0.10<sup>hrs</sup></b>	<b>95.25±<sup>1.36a</sup></b>	2.44±0.64 <sup>cds</sup>	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>tg</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±0.34 <sup>b</sup>	4.17±1.15 <sup>ab</sup>

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 for 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, and seeds of *Sesamum indicum* (16.29%). The cellulose content of *Vigna unguiculata* seeds is very low. Seed of *Vigna unguiculata* is so low in cellulose (1.48%). Compared to the calculated 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 **here is a significant difference between the results. Consider statistical analyses. Must be indicate in text.**

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), showed that legumes are richest in proteins and they are followed by fruit kernels. Fruit almonds had the highest lipid content. They were also the most abundant in cellulose. Furthermore, the highest carbohydrate content was observed in the pulp, cereal, and tuber categories. Finally, the vast majority of mineral elements were 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

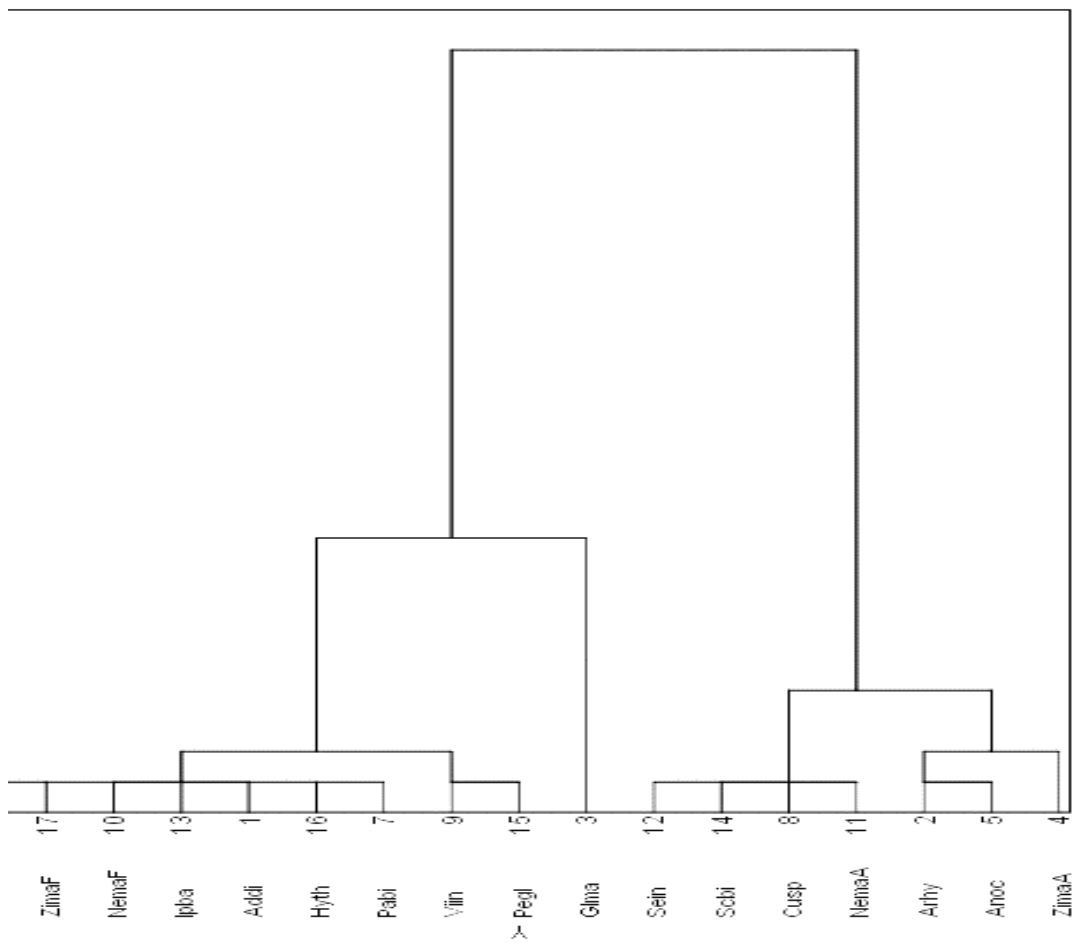


Figure 2: Ascending Hierarchical Classification of samples

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 aethiopicum* (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 ( $r = -0.75, p = 0.0000; r = -0.68, p = 0.0000; r = -0.54, p = 0.0000$ ) 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.

CHECK THE CORRECT PRESENTATION OF RESULTS IN ACCORDANCE WITH THE JOURNAL'S STANDARDS

**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)	0.710					
<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 ~~thatwhich~~ provide numerous products ~~thatwhich~~ are used by the ~~general~~ population, ~~inparticular in rural areasgeneral and in rural areas in particular~~. The food use of the latter mainly ~~concernseconcerned~~ fruits, pulps, leaves, flowers, seeds, and almonds [20]. The present study ~~involvedconcerned~~ 15 local plant species, ~~offrom~~ which 17 ~~weresamples~~ distributed as follows: 4 fruit pulps, 4 fruit almonds, 6 seeds, 2 tubers. Biochemical ~~analysesanalyzes~~ 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 ~~wereare~~ more interested in raw fibers (total fibers) than cellulose, as well as the different types of minerals and ash contents; ~~7~~ 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 showed presented water contents lower than 7%. This low content allows for observed allows their better conservation [21]. These rates are lower than those reported for in Togo on seeds (9 %)–which was 9%[8]. In Indeed, in the present this study, the highest water content was 6.72%. for 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 conducted carried out in Niger on two species of Cucurbitaceae (*Citrullus Colocynthis* and *Lagenaria siceraria*), whose water contente contents varied from 7 to 9.50% [22]. The baobab pulp was characterized by a water content that which was is close to that found by other authors, which varied from 6 to 15% [23]. In addition, baobab pulp is characterized by its prebiotic potential. Indeed, the fermentation of baobab pulp powder presents 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 of 9.7% has been reported was mentioned for baobab pulp pulps which was 9.7% (Ayosso et al., 2015).

The it appears from this present study shows that legumes and fruit kernels contain the highest levels of proteins protein and lipids. The Thus, the highest protein content value was observed in soybean (*Glycine max*) at 36.39%, followed by *Sclerocarya birrea* almond (30.84%), and the lowest that of the least was 2.11% in sweet potato (*Ipomoea batatas*). The results obtained are approximately similar to those found in soy varieties consumed in Burkina Fasso and Togo, with protein contents of 31.04% and 34.43 %, respectively 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 that which vary 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 ~~contenteontentswere~~ ~~was~~ 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 ~~werearehigherhighthaneompared to~~ those of the *Ipomoea tuberosa* ~~and~~, fruit pulps of *Adansonia digitata*, which ~~wereare~~ 0.20% and 0.44%, respectively. A previous study ~~by~~ in Niger noted a higher fat content of 67.5% for the almond *Neocarya macrophylla* [29]. The ~~observed variationsvariationsobserved~~ could be linked to the degree of maturity, genetic influence, temperature, sunshine, ~~and~~ 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]. ~~ConsideringTaking into account~~ its nutritional ~~benefitsvirtues~~, 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 ~~thatwhich~~ varied depending on the origin, from 38 to 56.3% fat, 4.58 to 22.5% carbohydrates, 3.60 to 4, ~~and~~ 58% ash [27]. ~~Other studies Others~~ have shown variability in nutritional characteristics ~~amongbetweenthe~~ 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 ~~inof~~ *Sesamum indicum* of 60.05%, 61.70%, 52.4 to 62.8%, ~~and~~ 49.83% to 59.85%, respectively [34–36].

The present study also ~~showedshows~~ that all fruit pulps, tubers, cereals, and some legumes ~~containedcontain~~ 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%, ~~and~~ 90.39%, and the lowest value ~~wasis~~ 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]. ~~HoweverOn the other hand~~, different results were reported ~~forfrom~~ the fruit pulp of *Ziziphus mauritiana*, which was 13.05% [38]. This difference could be ~~explainedjustified~~ by the methodology used ~~to determineduring the determination of the~~ carbohydrate content (spectrophotometric assay). ~~SimilarAswith to~~ *Adansonia digitata* fruit pulp, different results were reported ~~in by~~ 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

As shown in Table 3, legumes and fruit kernels are extremely rich in cellulose, with the exception of *Vigna unguiculata*. Thus, the highest values were reported for 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*, the seed of *Sesamum indicum* (16.29%), and the seed of *Vigna unguiculata* are very poor in cellulose (1.48%). Previous studies have reported different cellulose results for *Western Anacardium*, which varied according to provenance, including Kolda (14%), Ziguinchor (13.5%), and Sédhiou (9%) [33].

Compared to the *Neocarya macrophylla* almond, the *Neocarya macrophylla* almond had the highest energy value. The energy values of the analyzed samples oscillate between 392.24 and 748.93 Kcal/100g. The 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 the difference in the 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 the comparison of the averages of the biochemical parameters according to the food category to which the plant species belongs (Table 5), show that legumes have the highest average protein content of 26.27%, which is very close to that of fruit almonds (25.49%). This could mean that, whether legumes are available, fruit kernels can be used for their important role in the development, maintenance, and repair of tissues. In addition, fruit almonds had the highest lipid content (49.52%), followed by that of legumes (32.63%). However, the fat content varies, depending not only 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%, respectively. Almonds were also the richest in cellulose (19.97%) with a content of 19.97%, followed by legumes (12.14%) with a rate of 12.14%. As for mineral elements, the largest majority was found in fruit pulps with a content of 4.88%, followed by and legumes come in second position with a value of 3.18%. Regarding water contents, the highest water content is observed in cereals (6.72%), followed by pulps (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 were 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, and fruits with a high energy content had the poorest water content 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.

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 was 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 characteristic characterizing criterion of this group was the high protein value. Finally, the third group included concerns 18% of the samples studied, which are Arhy, Anoc, and 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 noted that the plant species studied presented 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*) ~~and which~~ can be used in different areas ~~such as~~: human food ~~and~~, 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 ~~exhibited showed a~~ significant energy ~~contributions~~ contribution.

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

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