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Full Length Research Paper

Physico-chemical and functional properties of *bâtchi* or hypocotyle axes of *Borassus aethiopum* Mart.

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The seed of the palm tree (*Borassus aethiopum* Mart.) at the beginning of its germination gives a hypocotyle axis which is consumed boiled or roasted by the populations of the Sahelian part of Africa. This present work was carried out to study its physico-chemical and functional properties. To this effect, macronutrients, minerals, anti-nutritional factors as well as some functional properties were evaluated on the dry powder of the seeds. The results obtained showed that the dry matter (DM) was 92.53 ± 0.89%. The total lipid content (10.73 ± 0.00 g/100 g DM) was important and higher than that of other roots and tubers. Total and soluble sugars represented 39.98 ± 0.20 and 2.72 ± 0.19 g/100 g DM respectively. The total starch content was 35. 23 ± 0.50 g/100 g DM, with resisting and digestible starch representing respectively 20.27 ± 0.24 g/100 g DM and 7.44 ± 0.38 g/100 g DM. The fibers content was 6.10 ± 0.22 g/100 g DM. Total ash represented 2.68 ± 0.04 g/100 g DM with: Total phosphorous (129.66 ± 3.26 mg/100 g of DM), calcium (119.48 ± 0.45 mg/100 g of DM), sodium (784.4 ± 18.16 mg/100 g of DM). The anti-nutritional factors contents were: Phenolic compounds (275.75 ± 53.54 mg/100 g DM); Tanins (239.76 ± 30.09 mg/100 g DM), Phytates (87.88 ± 19.59 mg/100 g DM) and Oxalates (0.98 ± 0.05 mg/100 g ms). The analyzes carried out on the functional properties of the hypocotyle axes revealed that the water absorption capacity, the index of solubility, the gelifying power and the time of gelification were 272.99 ± 15.13%, 31.83 ± 1.28%, 13% and 12 min respectively.

Key words: Hypocotyls (*bâtchi*), *Borassus aethiopum*, physicochemical properties, functional properties, Cameroon.

INTRODUCTION

The endemic resources contribute to a significant extent to the food and the economy of several developing countries (FAO, 1993). However, in spite of their potential importance and ancestral use as food, these wild trees classified in the category of the forest plants close to human beings in savanna zone, very few nutritional data are available concerning them. However, the investigations documenting their ethno-botanic aspects are well known (Kouyaté et al., 1998; Baumer, 1995; Khieu and Preston, 1995, Bergeret and Ribot, 1990; Morton, 1988; Morton, 1988). The palm tree (*Borassus aethiopum*, Mart), a many under-exploited endemic species, is a multi-purpose plant, which parts are subject to diverse usages and commercialized in both urban and rural areas of Cameroon. Hence, processing the palm tree products generates food and income to the craftsmen and households from villages bordering palm groves.

B. aethiopum bears fruit every 8 months and produces between 50 and 150 fruits (50 to 175 kg), depending on the size of the fruits. The edible fruits of *B. aethiopum* are gathered in tightened bunches, containing each two to three cores surrounded by a fibrous flesh. They are

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ovoids or smooth globulous and fibrous drupes, from 15 to 20 cm in diameter. Their color when at maturity is yellow, orange or slightly reddish. A sweet, viscous and scented juice is extracted from the ripe fruit, with fibrous mesocarp, which is used in the production of millet flurry or in the preparation of wafers of millet. The pulp, the seeds, the hypocotyle and the sap are used in various forms for human consumption. When the cores of the sucked fruits are sown, germination takes place at the end of one month and gives a seedling whose hypocotyle located under the cotyledons and full of reserve, is the subject of special culture for a local and regional consumption (FAO, 1993).

Commonly called 'Vackdolé' by the 'Dii' people or 'bâtchi' by the 'Fulani' of the Adamawa region of Cameroun, and 'miritchi' by 'Haoussa' of Niger, it is a product which has an appreciable taste and its aspect when cooked or roasted resembles to the roots of manioc. It is often transformed into flour for the preparation of the paste or the 'fufu' (Ibrahima, 2005). This food product which constitutes a constant in the food habits of the population of the production zones suffers from a lack of information on its nutritional value. Only some data exist on the composition of the pulp of fruits (Ali et al., 2010; Djibrilla, 2006)

The objective of this work was to valorize the 'bâtchï' by evaluating its nutritional properties. Specifically, the study focused on morphological characterization, determination of nutrients content and antinutritional factors of the product and on the study of some functional properties of the flour obtained by drying, grinding and sieving the product.

MATERIALS AND METHODS

Collection of plant material

The plant material was obtained from 'Dii' producers in the market of 'Karna Manga', district of 'Mbé' in Adamawa region, which geographic coordinates are between 7°03' and 7°32' North latitude and between 13°20' and 13°54' East longitude. Only non-damaged and film-protected axes were retained after sorting and were carried to the laboratory. The climate of the region is of Altitude Soudano-Guinean type with subequatorial tendency, the annual rainfall is 1479 mm (Tchotsoua et al., 1996).

Morphological characterization

The morphological characteristics were carried out on 50 entire and healthy hypocotyles axes. Measurements of the size, the diameter at the base, the median diameter, the mass were realized using a 0.001 g precision balance (PRECISA, France), a caliper square and a ruler.

Preparation of the samples for analysis

After the morphological characterization, 50 parts were de-fibered using a stainless steel knife, cut out in slices and then dried for 48 h at 45°C in forced convection drier (Standard CKA - AUF- 2000) (Kapseu et al., 2000). The dried slices were then ground using a hammer mill (Culati, France) and the powder obtained was sieved using a 1 mm stitch sieve. The flour obtained was characterized for the physicochemical and functional properties.

Chemical and functional analyses

The mass density was determined according to the method described by Okezi et al. (1988). The water and total ash contents of the hypocotyles axes were determined by normalized method (IUCPA, 1979). The total lipids were extracted in Soxhlet using hexane and were determined according to the Russian method described by Bourely (1982). The total starch was determined by the spectrophotometric method of Guggolz et al. (1950). The resistant starch was determined by enzymatic digestion using α-amylase and amyloglucosidase from *Aspergillus Niger* (Goni et al., 1996). The concentration in glucose was converted into resistant starch content using the factor of 0.9.

The difference between total starch and resistant starch represented the digestible starch (Goni et al., 1996). Soluble sugars and total sugars were extracted respectively with water and by hot hydrolysis with hydrochloric acid, then the content in these sugars were evaluated according to the method described by Fisher and Stein (1961). Crude proteins were mineralized by the method of Kjeldhal (AFNOR, 1981), and the nitrogen obtained was analyzed by the method of Devani et al. (1989). The crude proteins content was obtained by multiplying the nitrogen content by the conventional factor of 6.25. Fibers were determined by the method of Wolf (1968).

NDF fibers (Detergent Neutral Fiber), ADF (Acid Detergent Fiber), ADL (Acid Detergent Lignin) and total cellulose were evaluated by the method of Van Soest et al. (1991). The carotenoids content was obtained according to the method of Wolf (1968), while vitamin C was extracted by the technique of Harris and Ray (1935) and determined according to Evered (1960). Minerals and heavy metals (P, Ca, Mg, Na, Ag, Mn, Fe, Zn, Cu, Cd, Cr, Pb) were determined by atomic absorption spectrometry (AAS 50B, Australia) after solubilization of ashes in hydrochloric acid.

Phenolic compounds and tannins were extracted with ethanol (70%) and were evaluated using Folin-Ciocalteu reagent according to the method of Marigo (1973). Phytates were determined by the method of Brooks et al. (2001). Soluble oxalates were hot extracted with distilled water and total oxalates were hot extracted in a mixture of chlorhydric acid - distilled water (6N) (1/19: V/V). The two types of oxalates were measured after oxidation by potassium permanganate (0.098 N) in hot acid medium (sulphuric acid 1 N) according to the method described by Mois (1953). The saponin content was obtained according to afrosimetric method of Koziol (1990). α-amylases inhibitors were extracted according to Lonstaff and McNab (1991) and evaluated by the method of Piergiovani (1992) using iodine and the starch.

The apparent and real water absorption capacities were determined by the method of Philips et al. (1988). The apparent water absorption capacity is the quantity of water that can be retained by flour at room temperature and the real water absorption capacity is the quantity of water retained after hydration, draining and drying of flour at 105°C for 24 h. The solubility index was determined according to the method described by Anderson et al. (1969). The gelifying power and the time of gelification were evaluated by the method of Coffman and Garcia (1977).

Data analyses

The values were obtained for three repetitions per analyzed sample and expressed in means ± standard deviation.

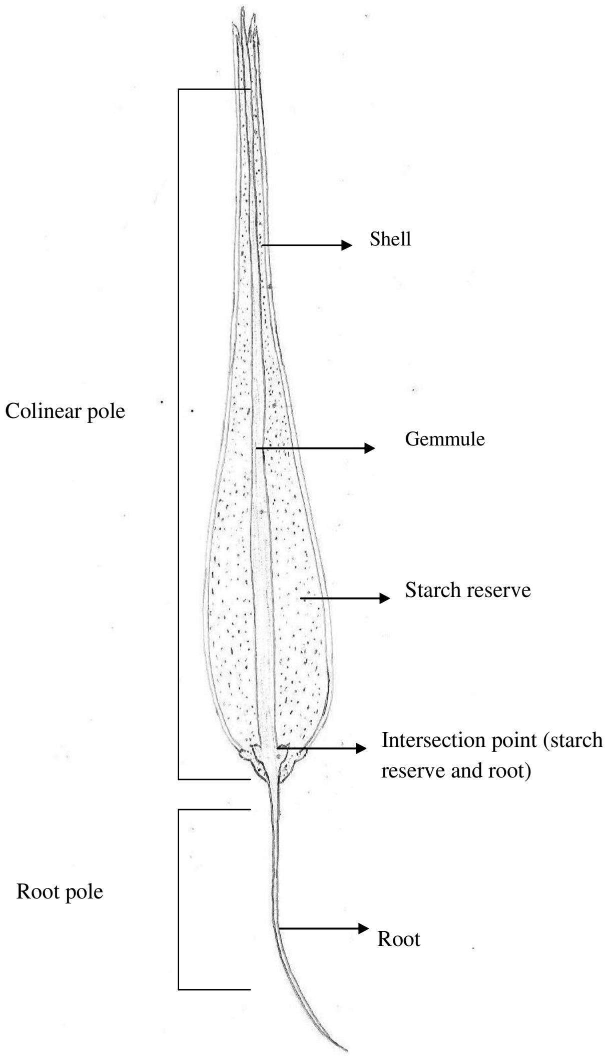

Figure 1. Cross-cut of hypocotyle axe of *B. aethiopum.* Mart.

RESULTS AND DISCUSSION

In order to characterize and to raise the nutritional and functional potentialities of 'bâtchï', the physical measurements were carried out on the raw product, and analyzes were made on the powder obtained after dehulling, cutting, drying, grinding and sieving of the hypocotyle axis.

Morphological characteristics of the hypocotyle axis of *B. aethiopum* Mart. (bâtchï)

The hypocotyle of the fruit of the palm tree locally called bâtchï is a yellow-whitish spindle-shaped bulge (Figure 1), of 25.94 ± 2.81 cm average length, 1.96 ± 0.89 cm median diameter, 3.08 ± 0.25 cm diameter at the base, and average mass of 90.44 ± 10.33 g.

Physico-chemical composition

The phyico-chemical analyzes were carried out in order to determine the nutritional value of the hypocotyle of *B. aethiopum* Mart flour. Table 1 presents the average contents of various components of this flour.

Water and total ashes contents

As indicated in Table 1, the flour of bâtchï with an average mass density of 1.73 ± 0,01 g/ml, is slightly hydrated with a dry matter content of 92.53 ± 0.89% and total ash content of 2.68 ± 0.04 g/100 g DM. The dry matter and ash contents are similar to those of the flour from the pulp of the fruit from the same tree which are of 91.79 ± 1.32 g/100 g DM and 2.7 ± 0.19 g/100 g DM, respectively (Djibrilla, 2006). Low water content is advantageous for the preservation of this food product.

Fat contents

The total lipids content of the bâtchï flour (10.73 ± 0.00 g/100 g DM) is relatively high when compared to that of *B. aethiopum* start-ups (0.2 g/100 g DM) (Glew et al., 2005). Similar comparison could be drawn with total lipid content of the pulp of the palm tree fruit (0.16 ± 0.001) (Ali et al., 2010), or with that of certain roots and tubers in particular for yam (*D. schimperiana*) with 1.4 g/100 g (Tchiegang and Ngueto, 2009); cassava (*Manihot escalenta* crantz) with 0.3 g/100 g of DM (Onwueme, 1978); for potato with 0.4% (Bradbury, 1988); for taro with 0.2% (Agbor-Egbe and Rickard, 1990); and 0.3% for the cassava (Rickard and Coursey, 1981). Given that the lipids required daily for the child is 4 and 1 g/kg/day for an adult (Malassis et al., 1992), the flour of bâtchï could be considered as a potential source of lipids, provided that the fatty acid composition is determined.

Crude proteins content

The flour of bâtchï is very low in proteins 0.017 ± 0.00 g/100 g DM when compared with the flour of the palm tree fruit pulp which contained 4.23 ± 0.32 g/100 g DM (Djibrilla, 2006), or with roots such as cassava with 1 g/100 g of DM (Onwueme, 1978) and yam (*D. schimperiana*) with more than 6.24 g/100 g of DM (Tchiegang and Ngueto, 2009). This flour could not be regarded as potential source of proteins.

Sugar contents

The flour of bâtchï contained 39.98 ± 0.20 g/100 g DM of total sugars and 2.72 ± 0.19 g/100 g DM of soluble

Table 1. Nutritional value of *bâtchï* flour (g/100g MS).

Parameters	'Bâtchï' flour	Flour from *B. athiopum* fruit pulp (Djibrilla, 2006; Ali et al., 2010)
Mass density (g/ml)	1.73 ± 0.01	-
Dry matter content	92.53 ± 0.89	91.79 ± 1.32
Total ash content	2.68 ± 0.04	2.7 ± 0.19
Total lipids	10.73 ± 0.00	0.16 ± 0.01
Crude proteins	0.017±0.00	4.23 ± 0.32
Soluble sugars	2.72 ± 0.19	19.01 ± 1.52
Total sugars	39.98 ± 0.20	22.86 ± 1.57
Total starch	35.23±0.50	-
Digestible starch	7.44±0.38	-
Resistant starch	20.27±0.24	-
Crude fibers	6.10 ± 0.22	29.75 ± 0.08
Neutral detergent fiber (NDF)	1.86 ± 0.19	-
Acid detergent fiber (ADF)	5.37 ± 0.03	-
Acid detergent lignin (ADL)	2.51 ± 0.11	-
Cellulose	2.86 ± 0.07	-

sugars. The flour is richer in total sugars and lower in soluble sugars than the flour from the palm tree fruit pulp which are respectively 22.86 ± 1.57 g/100 g DM and 19.01 ± 1.52 g/100 g DM (Djibrilla, 2006). The total sugar content of the bâtchï flour is higher than that of cassava (32 - 35 g/100 g), sweet potato (25 - 32 g/100 g) and taro (19 - 21 g/100 g) (Kay, 1987). The low sugar content soluble is justified by the fact that the hypocotyle constitutes a starch reserve that could be directly used by the seedling before the development of secondary roots.

Starch content

The flour obtained after drying, grinding and sieving, contains 35.23 ± 0.50 g/100 g DM of total starch, with respectively 7.44 ± 0.38 and 20.27 ± 0.24 g/100 g of digestible and resistant starch. Thus, 22% of the starch of the flour is digestible. This digestibility depends on the size of the granules (Snow and O' Dea, 1981), on the ratio amylose-amylopectin (Hoover and Sosulski, 1985), on the length of the amylose chain (Jood et al., 1988), and on the complex amylose-lipids (Holm et al., 1983). This last assertion can justify the low digestibility of the bâtchï starch which contains an appreciable content of lipids. However, research carried out by Pugalenthi et al. (2005) showed that the hydrothermal treatment improves considerably the bioavailability of the starch in *Mucuna* spp. seeds. This result confirms the richness of the bâtchï flour in carbohydrates in the form of starch.

Fibers content

The food fibers are defined as the sum of non starchy polysaccharides (cellulose, hemicelluloses, pectic substances) and lignins, which are mainly components of plant cell walls.

In spite of the dehulling and sieving previously carried out on the hypocotyles axes, which remove an important part of fibers, the bâtchï flour contained 6.10 ± 0.22 g/100 g DM of crude fibers and 2.86 ± 0.07 g/100 g DM of cellulose. The respective quantities of neutral detergent fibers (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) determined by the sequential method of Van Soest et al. (1991) are: 1.86 ± 0.19; 5.37 ± 0.03 and 2.51 ± 0,11g/100 g DM. The fraction ADL reveals the lignin content, which is the main constituent of the cell wall skeleton associated with its rigidity. This fraction ADL, as well as cellulose (ADF - ADL) are not very digestible. These fibers exhibited beneficial physiological effects to human body, as they stimulated and accelerated intestinal contraction and transit, and increased feces volume.

Carotenoids and vitamins contents

The bâtchï flour has a carotenoids content of 92.84 ± 0.00 mg/100 g DM, lower than that of the fresh pulp of the palm tree fruits (133.05 ± 4.17 mg/100 g DM), but higher than that of the dried pulp of the fruit's flour of the same tree (81.07 ± 2.86 mg/100 g DM) (Djibrilla, 2006). The vitamins A and C contents are respectively 15.47 ± 0.00 and 0.55 ± 0.00 mg/100 g DM. These contents are very weak compared to those of the fruit pulp flour which contains 81.07 ± 2.86 mg/100 g DM of vitamin A and 127.58 ± 6.07 mg/100 g DM of vitamin C (Djibrilla, 2006)

Minerals contents of the flour

Table 2 present the results of the analyzes carried out on

Table 2. Mineral composition of the flour (mg/100 g DM)

Parameter	*bâtchï* flour	*B. athiopum* fruit pulp (Ali et al., 2010)
Total phosphorous	154.40 ± 2.77	567.01 ± 0.43
Soluble phosphorous	129.66 ± 3.26	
Calcium	119.48 ± 0.45	108.25 ± 0.24
Magnesium	29.01 ± 0.11	21.01 ± 0.31
Sodium	784.4 ± 18.16	-
Silver	1.13 ± 0.01	-
Manganese	0.19 ± 0	-
Iron	0.51 ± 0	2.15 ± 0.20
Zinc	0.50 ± 0.02	-
Copper	2.18 ± 0.39	-
Chrome	0.68 ± 0.01	-
Cadmium	Nd	-
Lead	Nd	-

Nd: not determined.

Table 3. Contents of some anti-nutritional factors of the flour (mg/100 g DM).

Anti-nutritional factor	Amount (mg/100 g DM)
Phenolic compounds	275.75 ± 53.54
Tannins	239.76 ± 30.09
Phytates	87.88 ± 19.59
Total oxalates	0.98 ± 0.05
Solubles oxalates	0.69 ± 0.02
Saponins	2.18 ± 0.28
Amylase inhibitors	0

the flour ash of of *B. aethiopum* Mart. Hypocotyles. These results reveal interesting amounts of minerals in the flour. The values obtained (per 100 g DM) are: 154.40 ± 2.77 mg of total phosphorus including 129.66 ± 3.26 mg for soluble phosphorus; 119.48 ± 0.45 mg for calcium; 29.01 ± 0.11 mg for magnesium; 784.4 ± 18.16 mg for sodium; 0.19 ± 0 mg for manganese; 0.51 ± 0 mg for iron; 0.50 ± 0.02 mg for zinc; 2.18 ± 0.39 mg for copper and 1.13 ± 0.01 mg for silver.

Hence, this flour is richer in calcium, sodium and copper, and lower in iron and zinc that the tubers of yams (*D. dumetorum* (Kunth) pax) generally consumed in the Adamawa region. The average mineral contents of yam were: 161 mg/100 g for phosphorus, 42 mg/100 g for calcium, 57 mg/100 g for magnesium, 15.9 mg/100 g for sodium, 6.7 mg/100 g for iron, 1.9 mg/100 g for zinc and 1 mg/100 g for copper (Trèche, 1989; Agbor-Egbe and Trèche, 1996).

The analysis of heavy metal contents reveals the absence of cadmium, lead and cobalt, but the presence of chromium (0.68 ± 0 Mg).

Contents of some anti-nutritional factors of bâtchï flour

The determination of some anti-nutritional factors was carried out to check factors affecting the bioavailability of nutrients from the flour. The various contents obtained are summarized in Table 3.

These results show that the bâtchï flour has variable contents of anti-nutritional factors: Phenolic compounds (275.75 ± 53.54 mg/100 g DM); tannins (239.76 ± 30.09 mg/100 g DM); phytates (87.88 ± 19.59) total oxalates (0.98 ± 0.05 mg/100 g DM) with soluble oxalates representing 0.69 ± 0.02 mg/100 g DM; and saponins (2.18 ± 0.28 mg/100 g DM). The risks related to anti-nutritional factors are less important when compared to that of the flour of *Tacca leontopetaloides* roots. In effect, recent studies by Collinlaw et al. (2009) revealed values as high as 342.14 ± 0.30 mg/100g DM for polyphenols; 31.77 ± 1.67 mg/100 g DM for tannins; 321.48 ± 17.31 mg/100 g DM for total oxalates and 643.03 ± 33.20 mg/100 g DM for saponin. The antinutritional factors in

Table 4. Functional properties of the *bâtchï* flour.

Parameter	Value
Gelifying power	13 (%)
Time of gelification	12 (min)
Apparent water absorption capacities	154.37 ± 14.84
Real water absorption capacities	272.99 ± 15.13
Index of solubility in water	31.83 ± 1.28

the hypocotyles axes virtually do not represent any danger for human beings since they have been consumed for decades (Bebbe, 2009). Some of these substances, like phenolic compounds, are rather beneficial for human health since they are the main food antioxidants and are anti-cholesterol substances. In addition, the potential nutritional risk is considerably reduced by the cooking process under the combined effects of lessivation and the thermal destruction.

Functional properties of the bâtchi flour

The use of flours in the preparation of flurry depends largely on their interaction with water in the rehydration process. In this study, some functional properties (Table 4) of the bâtchï flour (with granulometry lower than 1 mm) were evaluated, in particular: Apparent and real water absorption capacities, the index of solubility in water, gelifying power and the time of gelification.

Water absorption capacity plays an important role in the quality of the texture of various foods (Cheftel et al., 1985). Wolf (1970) showed that water absorption capacity is an important property for flours used in pastry, since this property is used by pastrycooks to add water to the paste while improving its handling and to maintain freshness in the bread.

Other studies carried out on various flours reported water absorption capacities of 265 and 380% for the flours of *Phaseolus lunatus* and *Canavalis ensiformis* seeds (Chel-Guerrero et al., 2002); of 275% for the flour of niébé (Okezie and Bello, 1988) and of 454% for the flour of yams (Medoua, 2005). All these values are largely higher than that of the bâtchï flour. The low contents of structural proteins and hydrophilic carbohydrates in bâtchï flour would be responsible for the reduction in water absorption capacity of this flour. In this respect, it has been pointed out that the availability of functional groups of proteins in flours increases the water absorption capacity (Medoua, 2005).

The solubility index of the bâtchï flour (31.83 ± 1.28) is higher than that reported by Medoua (2005) for the flour of yam (14.7 ± 0.1). The relatively high gelifying power (13 ± 0.00), is justified by the presence of hemicellulose and cellulose.

Conclusion

The hypocotyle of the fruit of *B. aethiopum* or bâtchï is a nonconventional food resource potentially exploitable. Its flour presents an appreciable nutritional value with interesting lipids, mineral starch and fiber contents. In view of better food and technological valorization of this food product, very much appreciated and largely consumed in the Sahelian zones of Africa, it would be judicious to carry out thorough studies aiming at characterizing the type of starch and fibers of bâtchï, as well as the nature of the anti-nutritional factors which, in certain cases, can be beneficial.

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