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Biochemical composition and nutritional value of *Balanites aegyptiaca* (L.) Del fruit pulps from Northern Ferlo in Senegal

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Balanites aegyptiaca, a forest species of socio-economic interest for rural people, was chosen to be planted in the frame-work of the Great Green Wall project in Senegal. Although in vastly demand during food scarcity period before crops harvest, the species' fruit is poorly valued despite its important production. In this study, the fruit pulps were harvested at maturity and the biochemical characteristics were accessed in order to better understand the fruit's nutritional value. The moisture, sugars, proteins, amino acids, ash, fat, minerals and some vitamins were determined by standard methods of analysis. The results indicated that the fruits are a good alimentary source of sugar, minerals (mainly potassium) and ascorbic acid. The pulp proteins were qualitatively balanced, but were present only in weak quantities. Its caloric value is high due to the high concentration of sugars. Low humidity should allow a fairly good postharvest fruit conservation. The dietary intake of this fruit for local people is very valuable especially in terms of nutrition.

Key words: *Balanites aegyptiaca*, pulp, biochemical, nutritional value.

INTRODUCTION

Senegal is located in the Sahelian zone where woodland decline is attributable to many episodes of drought and anthropogenic pressures (MEPN, 2008). Today, with the proposed Pan-African Great Green Wall (vegetation belt of multi-species, 15 km wide linking Dakar to Djibouti, and about 7000 km long), the definition of strategies is based on the reintegration of local forests of multiple usages and plants species with socio-economic interests which are nowadays endangered. *Balanites aegyptiaca* is one of the species meeting these criteria. Its main value resides in its perfect adaptation to arid ecosystems (Chevallier et al., 2004) and good fruit production, consumed and traded mainly in food scarcity period (Broutin and Sokono, 1992). The ripe fruit is a drupe, which has a brownish to reddish thin epicarp, dark brown and fleshy mesocarp, and thick endocarp that contains a

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Abbreviations: AFNOR, Association Française de Normalisation; **CNRS,** Centre national de la recherche scientifique; **CREDOC,** Centre de recherche pour l'étude et l'observation des conditions de vie; **DM,** dry mater; **INEE,** Institut écologie et environnement; **OHMi,** Observatoire Homme Milieu (monitoring center man-environment).

nut (Eyog et al., 2000). It is very popular in traditional medicine for treating parasites, sore throat, constipation and eye irritation (Chevallier et al., 2004). From a nutritional standpoint, the fruit has been studied in a number of works. Its pulp is rich in carbohydrates and monounsaturated fat (Chothani and Vaghasiya, 2011). Nutritionally, Balanites leaves, flowers and fruit pulp are good sources of protein, K, Fe, Mn, Zn and Cu. *B. aegyptiaca* products are nutritionally and economically important for the rural dryland.

The phenological studies carried out in Senegal by Ndoye et al. (2003) showed that fruits of *B. aegyptiaca* are available during two seasons of the year: during the cool season (from December to February) and shortly before the rainy season (from May to July). Nevertheless, the potential of the fruit is underused and poorly valued despite its significant production. In this context, we are not only interested in inventorying the fruit's production in the Ferlo area, but also in analyzing the biochemical composition of its pulp to reveal its nutritional value and help promote its consumption.

MATERIALS AND METHODS

Biological material

The biological material consisted of ripe fruit of *B. aegyptiaca*; with the color used as the parameter to judge the fruit's ripeness. In *B. aegyptiaca*, the green color of the fruit is associated with immaturity and the yellow to reddish color with maturity (Eyog et al., 2000) (Figure 1). It is known that the change of the fruit's color to brownish-reddish at the maturation stage is attributed to the gradual degradation of chlorophylls that allow the appearance of other pigments. The samples were collected from the rural community of Téssekéré (15° 51' 47.5" N / 15° 05' 53.2" W) in northern Senegal, belonging to the eco-geographical region of Ferlo. Tessékéré is a locality in the green wall zone where the Monitoring Center Man-Environment (OHMi) of the CNRS-INEE is located. It includes several specialists of ecology, botany, ethnobotanic, medicine and nutrition working in an interdisciplinary environment. For this reason, this locality was an ideal site to conduct this research. The collection of fruits was carried out in natural populations of the species between December 2010 and January 2011. To have a representative sample, fruits were collected randomly from twenty-five (25) trees. The mass of fruit intended for biochemical analyzes was 3 kg. Two sets of 1.5 kg samples were stripped of their outer layer and pulped by moderate mechanical pressure.

Analysis methods

Pulp samples were analyzed using several physico-chemical parameters. Moisture content was determined by drying the samples in an oven at 105°C for 12 h. The ash was obtained by incineration in an electric oven at 550°C. The fat was extracted in the Soxhlet's extractor using diethyl ether. The total nitrogen content was determined by the Kjeldahl's method (Bremner and Mulvaney, 1982). From the nitrogen content, a conversion factor of 5.18 was used in connection with the AFNOR standards to estimate the fruit's protein content. The acidity was determined by titration of pulp juice (10 g of pulp dissolved into 10 ml of distilled water) with sodium hydroxide (NaOH, 0.1 N) in the presence of phenol-phthalein (AFNOR, 1982). After digesting the pulp sample dried at 500°C, the mineral elements were determined by emission spectrometry of inductive coupled plasma (ICP Varian Vista CCD detector). Other compounds in the pulp were analyzed by high performance liquid chromatography (HPLC).

-Ascorbic acid was determined as described by Contreras-Oliva et al. (2010) with the following minor modifications. The substance was extracted by adding 4.5% metaphosphoric acid (*w/v*), and the mixture was eluted with 1% sulfuric acid (H_2SO_4). Afterward, the extracts were filtered through a 0.45-um Millipore filter before being analyzed by HPLC. The equipment used was a chromatograph (HPLC) Varian® equipped with a quaternary pump, automatic injector and photodiode array detector, using LiChospher column RP-18, 5 μm, 4.6 × 250 mm.
-Levels of β-carotene and tocopherols were determined according to the method of Schieber et al. (2002). The extraction of the substances was carried out using ethanol/hexane (4/3 V/V) and chromatographic analysis was performed using an analytical scale (250 × 4.6 mm) C_{30} reversed phase column with a particle size of 5 μm (YMC, Wilmington, USA).
-Sugars were extracted with ethanol 80%, determined on Carbo Pac MA1 column (4 × 250 mm, 7.5 μm) in a mobile phase of NaOH (0.6 to 0.8 M) and detected by amperometry, according to the study of Yu et al. (2002).
-The amino acid profile was determined by anion exchange column with gradient elution cationic citrate buffer 2.25<pH<8.2 after hydrolysis with 4M methanesulphonic acid at 150°C for 120 min. Their detection was performed following to the study of Yu et al. (2002).

For each parameter analyzed three repetitions were made.

Data analyses

The energy value of the pulp was taken from carbohydrate contents, lipid and protein, to which we applied energy coefficients of Atwater: 4 kcal for carbohydrates and proteins and 9 kcal for lipids (Favier et al., 1993). The energy content of food is primarily determined by the Atwater factors; a system largely developed from the experimental studies of Atwater and his colleagues in the later part of the 19th century and currently applied by other researchers such as Kruskall et al. (2003). The ratio (R) of the total sugar level out of the humidity rate in fruit was used as a quality index to characterize fruits of *B. aegyptiaca*. This index is determined by the following formula (Reynes et al., 1994):

$$R = \frac{\text{Total sugar}}{\text{Water content}}$$

Three levels of fruit quality are recognized following the ratio (R):

- For an R value greater than 3.5 (R>3.5), the fruit is dry;
- If R varies between 3.5 and 2 (2<R<3.5), the fruit is semi-dry;
- For an R value less than 2 (R <2), the fruit is humid.

The statistical analysis of the data (averages and standard deviations) was performed using an Excel spreadsheet with a confidence level of 95%. Most of the parameters have been put in the same unit (data for 100 g of dry matter) for comparison. In addition, the nutritional value was compared to other fruits available in Africa.

RESULTS AND DISCUSSION

Water content

The results of the laboratory analysis on physical and

Figure 1. Immature (a) Photo M.B. Sagna (January 2011) and mature fruits (b) of *Balanites aegyptiaca* (L.) Del. This has been changed to brownish.

Table 1. Composition in organic and mineral elements of pulp.

Parameter		Content (mean ± SEM)
	Total sugars	42.57 ± 0.35
Organic elements (g 100 g^{-1} DM)	Proteins	9.57 ± 0.01
	Fats	0.41 ± 0.01
Ash (g 100 g^{-1} DM)		9.06 ± 0.26
Humidity (%)		16.31 ± 1.07
Titratable acidity (meq 100 g^{-1})		17.5 ± 0.1
	Ascorbic acid	6.87 ± 0.1
Vitamins (mg 100 g^{-1} DM)	ß-carotene	-
	Tocopherol	-

(The values obtained are the mean of three repeat). DM, Dry matter.

chemical constituents of fruit pulp are shown in Table 1. The average water content of fruit pulp was around 16.31%. It was close to those reported by Soloviev et al. (2004), varying between 14.6 to 24.1%. This result reflected the non-succulent characteristic of these fruits, supporting the semi-dry or dry qualification given to them by Ben Salah and Hellali (2011). The humidity is associated with the quality index to give a prediction of fruit condition during storage. The quality index of *B. aegyptiaca* fruits was valued at 2.6, and fruits having a similar index are considered as semi-dry (Reynes et al., 1994). The combination of these two parameters reflects the ability of the fruit to have a long storage under ambient conditions and limits the proliferation of microorganisms, agents responsible for food components deterioration (Reynes et al., 1994; Ben Salah and Hellali, 2011).

The main sugars

Sugars were the dominant constituents (42.60 ± 0.63 g 100 g^{-1} DM) (Table 4). This content was relatively high compared to the 33 g 100 g^{-1} of dry pulp reported by Favier et al. (1993). Several factors may explain these variations: the impact of soil and climatic conditions, the maturity of analyzed fruits, or changes in analysis methods used. The comparison with other Sudano-Sahelian fruit species showed that sugar content of fruit pulp of *B. aegyptiaca* was comparable to *Ziziphus mauritiana* (37.6 g 100 g^{-1} DM) (Danthu et al., 2002), less important than that of *Phoenix dactylifera* (69.9 g 100 g^{-1} DM) (Favier et al., 1993), *Detarium microcarpum* (64.47 g 100 g^{-1} DM)

Table 2. Essential and non essentials amino acids in the pulp.

Amino acid		Mean ± SEM (mg 100 g^{-1} DM)
Essential amino acids	Leucine	260 ± 0.03
	Valine	242.5 ± 0.02
	Lysine	212.5 ± 0.03
	Isoleucine	170 ± 0.02
	Phenylalanine	137.5 ± 0.02
	Threonine	132.5 ± 0.02
	Histidine	107.5 ± 0.01
	Methionine	77.5 ± 0.01
Non-essential amino acids	Proline	1172.5 ± 0.13
	Glutamic acid	465 ± 0.06
	Aspartic acid	312.5 ± 0.04
	Alanine	212.5 ± 0.03
	Tyrosine	177.5 ± 0.01
	Arginine	155 ± 0.02
	Serine	152.5 ± 0.04
	Cysteine	120 ± 0.01

(The values obtained are the mean of three repeat). DM, Dry matter.

(Kouyaté et al., 2009) and *Maerua pseudopetalosa* (67.72 g 100 g^{-1} DM) (Kouyaté et al., 2009) fruits, but higher than those of *Adansonia digitata* (7.2 to 11.8 g 100 g^{-1} DM) and *Tamarindus indica* (14.4 to 18.6 g 100 g^{-1} DM) (Soloviev et al., 2004). This similar or higher level of sugar content comparatively to the other well-consumed local fruits indicates that *Balanites* could be better consumed by local people when good information is provided.

At maturity, carbohydrates in the fruit's pulp are essentially reducing sugars (glucose, 17.7 ± 0.20 g 100 g^{-1} DM; and fructose, 17.3 ± 0.17 g 100 g^{-1} DM), which represent 82% of total sugars. On the other hand, sucrose (7.6 ± 0.26 g 100 g^{-1} DM) represented 18% of total sugars. In contrast, no trace of sorbitol was detected (data not shown). Studies on *P. dactylifera* sugars gave proportions comparable to our findings, with 85% of reducing sugars (glucose and fructose) and 15% of sucrose. In terms of nutrition, the role of sugars is not limited to energy intake; they play a vital role in both the taste of food and the pleasure of eating (CREDOC, 2000). In relation to this aspect, the fruit of *B. aegyptiaca* is known for both its sweet and bitter taste, the bitterness being related to sapogenins found in the mesocarp (Chothani and Vaghasiya, 2011), and sometimes annoying the consumers. However, this annoyance seems to be minimal with some of the local people who do not pay much attention to the bitterness. The results of this analysis show a high concentration of fructose in the *Balanites* fruit's pulp. A high consumption of this sugar form might be hazardous to humans, because it suspiciously parallels increases in obesity, diabetes, and a nonalcoholic fatty liver disease.

Another effect of high fructose intake is insulin resistance, a precursor to diabetes. These complications may arise when too much fructose is consumed whether it comes from cane sugar, beet sugar, high-fructose corn syrup. However, fructose delivered via fruit may not be as bad because we tend to get it in smaller amounts.

Proteins in the pulp

The results showed a protein content of 9.06 g 100 g^{-1} of dry pulp. This value was similar to the value of 9.2 g 100 g^{-1} found by Libouga et al. (2006). This protein content is comparable to that of cereals, ranging between 9 and 12% (Toury et al., 1966). The mesocarp proteins of *B. aegyptiaca* have many applications. Their use as coagulate into cheese gave significant yields (37.3 to 59.3%), but lower than those given by the protein rennet (Libouga et al., 2006). The analysis of their amino acid profile reveals sixteen (16) amino acids (Figure 2). The fruit analyzed by Favier et al. (1993) provides a similar amino acid profile. In fact, fifteen (15) amino acids have been reported by these authors, including glycine, without proline, threonine. The quantitative evaluation of amino acid pulp showed a low dietary intake of 4.1 g 100 g^{-1} DM, against 36 g 100 g^{-1} for FAO reference (El-Adawy and Khalil, 1994). Despite this relatively low content, the amino acids of the pulp are qualitatively balanced and are comparable to those of Senegalese fruits *M. pseudopetalosa* (Ayessou et al., 2009). The mesocarp of *B. aegyptiaca* fruit indeed, contains eight (8) amino acids which are essential for human consumption (Dillon, 1992) (Table 2). These amino acids are able to supplement

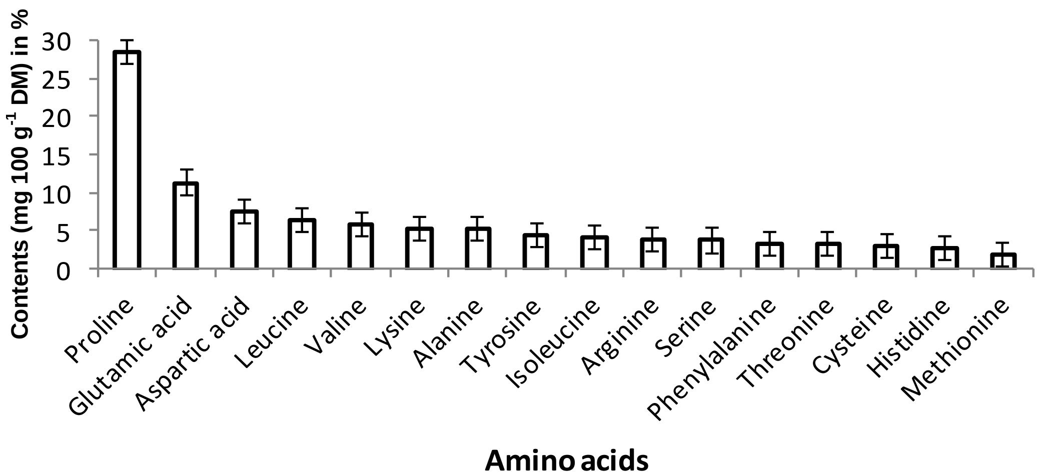

Figure 2. Profile of pulp's amino acids. (The errors bars indicate the SEM).

diets of little diversity, especially when the diets are based on cereals.

The amino acid profile of the fruit pulp reveals that proline is dominant. Its use in strategies to fight against plant stress and abiotic stresses has been demonstrated by several authors (Belkhodja and Benkablia, 2000). Its mobilization by the plant for the acquisition of abiotic stresses resistance in the Sahel would be probable.

The fat content of pulp

The fat was present in an extremely low amount at the rate of 0.41 g 100 g^{-1} of dry pulp. Favier et al. (1993) measured an almost similar content (0.1 g 100 g^{-1} DM). However, it is known that low levels of lipids are common in fruit pulp and are usually less than 1 g 100 g^{-1} DM, and would not have a great nutritional importance.

The ash and mineral richness

It is clear from our results that the total ash content of 9.57 g 100 g^{-1} of pulp dry matter is significant. The amount of ash significantly influences the content of mineral salts. Indeed, the minerals detected confirm this mineralogical richness. In our result, we notice a clear dominance of the micronutrients (Ca, Mg and P). Many trace elements (Fe, Zn, Cu, Mn) are also identified (Table 3). The mineral content of the pulp are consistent with those found in the literature (Mohamed et al., 2002). Their presence in the diet is desirable to ensure proper mineral nutrition in humans. It should be noted that the cons of *B*. *aegyptiaca* fruit is an excellent source of potassium (2220 mg 100 g^{-1}). This contribution is higher than that of banana and avocado, known for their richness in potassium between 400 and 570 mg 100 g^{-1} dry matter.

From a nutritional standpoint, a significant amount of dietary potassium is recommended especially in the context of primary prevention of hypertension or in case of acute or chronic renal failure (He and Whelton, 1997).

Acidity and vitamins content in pulp

Samples have a titratable acidity of 17.5 meq 100 g^{-1} of pulp. The acidity is a key element in the perception oftaste quality of fruit by consumers, and that of the *B*. *aegyptiaca* pulp is relatively high compared to the acceptability threshold which is 13 meq 100 g^{-1} (Praden, 1985). It may however be masked by sugar and bitterness (Signoret, 2004). Concerning vitamins, the amount of ascorbic acid dosage was 6.87 mg 100 g^{-1} fresh pulp; which is a relatively good rate. Favier et al. (1993) measured a lower content of 3.8 mg 100 g^{-1} of fresh pulp. This difference should be interpreted with caution since several studies have demonstrated the impact of storage on fruit quality, changes in titratable acidity and ascorbic acid (Kouyaté et al., 2009). The β-carotene and tocopherols (considered as powerful antioxidants) were not identified. As a general rule, tocopherols in tropical fruits are low, ranging between 0.1 and 1.8 mg. The mesocarp of the fruit contained other vitamins, the majority of which were in Group B, which are the vitamins B1, B2, B3 and B6 with 0.2, 0.1, 1.4 and 0.3 mg 100 g^{-1} pulp, respectively; reaching their maximum values when the fruit is perfectly ripe (Favier et al., 1993).

Energy value of pulp

The caloric intake derived from the pulp content in the term of protein, sugar and fat gave a value of 212.25 kcal 100 g^{-1} pulp (Table 4). This caloric intake was lower than the value of 300 kcal 100 g^{-1} of pulp stated by Nour et al. (1985) in Sudan fruits. It should be noted that the fruit pulp of *B*. *aegyptiaca* has a caloric intake greater than

Table 3. Minerals composition of the pulp.

Mineral		Contents ± SEM (mg 100 g^{-1} DM)
	Potassium (K)	2220 ± 0.06
	Calcium (Ca)	141 ± 0.01
Microelements	Magnesium (Mg)	73 ± 0.03
	Sodium (Na)	48 ± 0.02
	Phosphorus (P)	48 ± 0.02
	Iron (Fe)	4.94 ± 0.01
	Zinc (Zn)	0.65 ± 0.01
Microelements	Copper (Cu)	0.39 ±0.01
	Manganese (Mn)	0.33 ± 0.01
	Selenium (Se)	0.05 ± 0.01

(The values obtained are the mean of three repeat). DM, Dry matter.

Table 4. Calorific value of *Balanites aegyptiaca* fruits' pulp.

Parameter	Contents (g 100 g^{-1} DM)	Energetic coefficient	Calorific value (kcal 100 g^{-1})
Total sugars	42.57 ± 0.35	4	170.4 ± 1,3
Proteins	9.57 ± 0.01	4	38.28 ± 0.4
Fats	0.41 ± 0.01	9	3.69 ± 0.09
Total			212.25 ± 1.79

(The values obtained are the mean of three repeat). DM, Dry matter.

that of several tropical fruits, for example: banana (89 kcal), durian (126 kcal) and avocado (139 kcal) (Danthu et al., 2002). It can therefore be an important energy booster especially in poor rural areas, where food is mainly based on cereals.

In conclusion, the biochemical characteristics of *B. aegyptiaca* fruit pulp collected in the Ferlo region in Senegal showed an acceptable nutritional quality, with a high energy value due to sugars. Proteins in pulps are qualitatively balanced, but remain low in quantity. They are a good source of essential amino acids for human consumption. As in most fruits, potassium is the predominant inorganic compound, while calcium, magnesium and iron were also identified in significant amounts. The pulp of *B. aegyptiaca* also contains a significant amount of ascorbic acid. It has biochemical characteristics which allow good postharvest conservation.

The fruit of *B. aegyptiaca* could be of significant nutritional contribution to local populations, despite the lack of interest for this resource in comparison to other substances with similar nutritional value. Further biochemical studies are necessary. Such studies include the determination of the contents of phenolic compounds, tannins, oxalates, and mucilage responsible for the toxicity or bitterness observed in wild fruits; researches on fruit processing and improvement of their organoleptic characteristics; further researches on the therapeutic properties of the fruit to better understand its use in traditional medicine; and researches on genetic variability for its genetic improvement. Such information would help to pay more attention and give a better value to *Balanites* species.

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