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Intake Nutritional Variabilities of *Saba senegalensis* Fruits

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Abstract

Saba senegalensis is a popular wild fruit; which is consumed as such or transformed into various products. Despite its economic potential, its nutritional potential is unknown. The objective of this study is to characterize its fruits according to Senegal's main production areas. The study included five samples from five geographical areas of Senegal. Parameters measured include pH, protein, lipids, ash, moisture, vitamin C, carotenoids, polyphenols, minerals, and sugars. The results showed that for moisture, proteins, lipids, pH and reducing sugars did not differ significantly ($p < 0.05\%$) for all accessions. Vitamin C content varies between 32.86 and 198.22 mg·100g^{-1}, carotenoids with a content of between 5.05 and 9.12 mg·100g^{-1}; polyphenol contents are between 1.17 and 2.56 g·100g^{-1}. The nutritional value of *Saba* fruits appears to be homogeneous in Senegal. A thorough study of the functional molecules seems necessary for a better appreciation of the potential of this fruit.

Keywords

Saba senegalensis, Nutrition, Vitamine C, Polyphénols, Carotenoids

1. Introduction

Saba senegalensis is a non-woody and lianascent forest, its fruit is a large ovoid, bumpy, 7 - 10 cm long [1] [2] and 6 - 8 cm wide which is coated with translucent yellow fibrous pulp only [2]. In Senegal, it is found in the regions of Casamance (southern Senegal) and Kedougou (eastern Senegal). It is a plant that has enormous economic virtues, from the fruit to the roots through the leaves, bark, and latex. The fruit is highly prized by the population and can be consumed or processed into puree, nectar, jams, preserves and jelly [3] [4] [5] [6].

Previous works showed that the fruit is very rich in vitamin C [7] and is also characterized by water content closed to 80% [8]. The titratable acidity is high and explains the acid taste of the fruit due to a malic acid concentration [9]. One of the characteristics of *Saba senegalensis* is the level of β-carotene (vitamin A) [10].

Despite its high economic potential, the fruit of *Saba senegalensis* remains under-exploited and its nutritional potential, according to secondary metabolite is unknown [11]. Therefore, the evaluation of the nutritional potential is needed to increase the value of this fruit by local populations. Then, macronutrients and micronutrients such as total minerals, polyphenol, sugar, ascorbic acid and carotenoides analysis were purchased. The objective of this study is to complete the physicochemical and biochemical plan of the fruit of *Saba senegalensis.*

2. Material and Method

2.1. Collection and Sampling

The fruits are harvested in August 2016 in five sectors of two main production areas in Senegal (Bayla, Youtou, Niamone for Casamance's; Bandafasse and Salémata for Kédougou's region) (**Table 1**). Lots of fruits are selected from different production areas, at similarly sized fruit of the same ripening stage. Three samples are collected for each site. Fruits are the opened and depulped. Each of the three samples was analyzed in triplicate analytical methods. The resulting amounts are stored at −80˚C.

2.2.1. Major Macronutrients

Many volumetric dosages have been carried out according to the procedure described in the AFNOR standards [12] such as pH by direct measure (NF V methods); the water content by dehydratation (method NF V 03-707); Total Lipids by Soxhlet (method NFV 03-905 standard); total crude protein by Kjeldhal's method (NF 03-050 standard) and proteins were calculated using 5.7 as coefficient. The total minerals were determined after 3 hours incineration at 550˚C (V76-101 standard). The pulp acidity was titrated by using 0.1N Sodium hydroxide (NaOH). The value was expressed in mEg/100g of pulp wet matter.

2.2.2. Micronutrients: Sugar, Ascorbic Acid, Polyphenols, Carotenoides and Minerals

The sugar composition was determined by Dionex DX600 HPLC, after using a

Table 1. Caractéristiques des zones d'échantillonnage.

Productions areas		Bayla	Youtou	Niamone	Bandafassi	Salemata
Department		Ziguinchor	Oussouye	Bignona	Bandafasse	Salemata
Geographic coordinates	latitude	12˚53'39"N	12˚22'47"N	12˚44'33"N	12˚32'22"N	12˚37'42"N
	longitude	16˚21'8"W	16˚29'19"W	16˚20'4"W	12˚18'38"W	12˚48'59"W

volume of 80% ethanol for extraction. A CarboPac MA1 (4 × 250 mm; 7.5 µm) colon was used, and 0.6 to 0.8 of NaOH solution, with a 0.4 mL/min constituted the mobile phase [13]. The ascorbic acid was quantified by using HPLC RP 18^e Licrospher 100 column (Spectra SCM 1000Thermo Scientifique) with 0.01% of isocratic H_2SO_4 elution and 254 nm detection of UV 3000 Spectra [13]. Carotenoids contents were determined by HPLC (1100 Agilent with iodine detector) after extraction using mixture of ethanol/hexane [14]. The total polyphenols of each sample were defined by the Folin-Ciocalteu method. The dilute aqueous solution of each extract (0.5 ml) was mixed with the Folin Ciocalteu reagent (0.2 N, 2.5 ml) for 5 minutes and then 2 ml of sodium carbonate solution (75 g·L^{-1} in water) was added. After 2 hours of incubation, the absorbances were measured at 760 nm and traced by gallic acid acid (0-200 mg·L^{-1}). The results were expressed in mg of equivalents of gallic acid (GAE) per 100 g of fruit weight. For minerals determination, a mineralization at 500 ˚C was conducted and desilication with fluorihydric acid was performed after weighting. The detection of sodium, potassium, calcium, magnesium, phosphorus, copper, zinc and iron were realized by using a spectrophotometer of plasma radiation with inductive coupling of Varian-vista type.

2.2.3. Statistical Analysis

All statistical analyzes were carried out with the software R (version 3.2.4, 2016). Principal component analysis (PCA) and numerical classification were performed on the physicochemical and biochemical data in order to find the best correlations between the random variables. Also, the results obtained were studied by correlation analyzes (Pearson correlation coefficients) between the different parameters. To compare the means, the variance analyzes with the Fisher LSD test at the 5% significance level were also performed.

3. Results

3.1. Proximate and Mineral Nutrients

The results of physicochemical and biochemical analyzes of *Saba senegalensis*'s fruits of the five (5) localities are recorded in **Table 1**. Data processing by variance analysis shows that there is no significant difference ($p < 0.05$) of pH, water content, protein, lipid, and reducing sugar levels of samples from different origin. According to that, the characteristic mean values to be considered are 2.79 for the pH, 74.77% for the humidity; 0.22% for proteins; 1.25% for lipids; 13.38% for reducing sugars.

However, significant differences depending on the collection sites are noted on the other parameters measured. The titratable acidity represented by citric acid ranges from 2.33 (Youtou) to 1.85 g·100g^{-1} (Niamone). Bayla recorded higher ascorbic acid (198.22 mg·100g^{-1}) followed by Youtou (154.96 mg·100g^{-1}) and Niamone (145.59 mg·100g^{-1}). These levels are well above the average value for all localities combined (118.02 mg·100g^{-1}). In addition, the fruits collected in Bandafasse and Salémata have vitamin C contents lower than the average value of any locality being respectively 58.450 mg·100g^{-1} and 32.862 mg·100g^{-1}. The total sugar content varies from 12.68 (Salémata) to 15.1 mg·100g^{-1} (Bandafasse).

The ash contents are low but no difference is noted between the samples of Bayla (1.15 g·100g^{-1}), Niamone (1.52 g·100g^{-1}), Youtou (1.29 g·100g^{-1}), Bandafasse (1.44 g·100g^{-1}) and Salémata (1.45 g·100g^{-1}).

The polyphenol contents are variable for all localities. Indeed, the highest content was recorded on the Salémata samples (2.56 g·100g^{-1}) followed by Niamone (2.24 g·100g^{-1}), Bandafasse (1.94 g·100g^{-1}), Youtou (1.68 g·100g^{-1}) and Bayla (1.17 g·100g^{-1}). The carotenoid content varied depending on the collection areas. It is more important at Youtou (9.12 g·100g^{-1}) followed by Salémata (7.20 g·100g^{-1}), Bayla (7.11 g·100g^{-1}) and Niamone (6.86 g·100g^{-1}). These last three datas did not show significant differences, however these values are very different from those of Bandafassi (5.05 g·100g^{-1}).

The highest glucose levels are 3.66 and 3.19 g·100g^{-1}, respectively for the fruits collected at Bandafasse and Bayla but those from Youtou (3.14 g·100g^{-1}), Salémata (2.50 g·100g^{-1}) and Niamone (3.03 g·100g^{-1}) are weaker and similar. For fructose, the highest fructose fruits are recorded at Bayla (3.52 g·100g^{-1}) and the lowest in Salémata (1.76 g·100g^{-1}).

Table 2 shows the mineral composition of the pulp of the five localities. The results show that the calcium contents are very variable: from 113.86 (Bandafasse) to 1279.2 mg·100g^{-1} (Niamone); the potassium from 151.15 (Youtou) at 218.03 mg·100g^{-1} (Bandafasse); the sodium from 0.82 (Salemata) to 23.59 mg·100g^{-1} (Bayla); the magnesium from 24.03 (Youtou) to 30.91 mg·100g^{-1} (Bandafasse); the phosphorus from 9.86 (Youtou) to 13.98 mg·100g^{-1} (Salemata); the iron from 0.89 (Youtou) to 1.77 mg·100g^{-1} (Niamone).

3.2. Principal Components Analysis

A principal component analysis (PCA) was performed to evaluate the effect of provenance on the physicochemical and biochemical characteristics of the collected fruits. The results show that the two axes express 75.20% of the total variance (**Table 3**). A significant portion of the information contained in the data table is retained. The pH variables, total sugars, reducing sugars and glucose are positively well correlated with the first axis, while the water content variables, lipids and carotenoids are negatively. The parameters used to evaluate the sweet and acidic taste of fruits are well aligned on this first dimension (Dim 1), which could be considered as an organoleptic axis. The second dimension (Dim 2) is characterized by the polyphenol and ash variables that are positively correlated, as well as the fructose and vitamin C variables that are negatively correlated. Thus, this second dimension could be considered as the axis of the antioxidant potential of the fruits. The dimensions axes (Dim1 and Dim 2) delimit the types of fruits collected. The position on the axis Dim 1 differentiates the fruits rich in proteins, glucose, reducing sugars, total sugars and pH (Bandafasse), with the other fruits characterized by low acidity, moisture, lipids and carotenoids (Youtou).

Table 2. Physicochemical and biochemical characteristics of *Saba senegalensis* from five geographical areas of Senegal.

	SOUTHERN REGION		EASTEN REGION		
Paramètres	Youtou	Bayla	Niamone	Salémata	Bandafasse
Moisture (g/100g)	75.16 ± 1.06^{a}	74.77 ± 0.84^{a}	74.34 ± 0.93^{a}	75.34 ± 0.27^{a}	74.24± 0.43^{a}
Protéins (g/100g)	0.22 ± 0.03^{a}	0.22 ± 0.02^{a}	0.22 ± 0.02^{a}	0.24 ± 0.01^{a}	0.21 ± 0.02^{a}
Lipids (g/100g)	1.66 ± 0.51^{b}	0.96 ± 0.30^{a}	1.10 ± 0.26^{a}	1.33 ± 0.20^{ab}	1.16 ± 0.05^{ab}
pH	2.72 ± 0.11^{a}	2.85 ± 0.14^{a}	2.84 ± 0.02^{a}	2.75 ± 0.05^{a}	2.81 ± 0.08^{a}
Titrable acidity (mE/100g)	69.80 ± 0.53^{c}	37.80 ± 5.21^{b}	48.62 ± 1.30^{a}	48.91 ± 0.52^{a}	48.70 ± 6.02^{a}
Citric Acid (g/100g)	2.33 ± 1.16^{a}	2.27 ± 0.75^{a}	1.85 ± 0.57^{b}	1.99 ± 1.17^{bc}	2.15 ± 1.66^{ac}
Total Sugar (g/100g)	13.12 ± 0.04^{a}	13.78 ± 0.66^{ab}	14.09 ± 0.63^{ab}	12.68 ± 0.36^{a}	15.15 ± 1.81^{b}
Reducting Sugar (g/100g)	13.02 ± 0.58^{ab}	13.14 ± 0.26^{ab}	13.35 ± 0.04^{ab}	12.83 ± 1.16^{a}	14.57 ± 0.69^{b}
Glucose (g/100g)	3.14 ± 0.18^{ab}	3.19 ± 0.59^{a}	3.02 ± 0.20^{ab}	2.50 ± 0.30^{b}	3.66 ± 0.39^{a}
Fructose (g/100g)	2.84 ± 0.00^{ab}	3.52 ± 0.25^{c}	2.781 ± 0.37^{a}	1.762 ± 0.01^{d}	3.17 ± 0.06^{bc}
Ascorbic acid (g/100g)	154.96 ± 28.43^{b}	198.22 ± 13.11^{c}	145.59 ± 34.39^{b}	32.86 ± 10.18^{a}	58.45 ± 7.95^{a}
Polyphenols (g GAE/100g)	1.68 ± 0.01^{b}	1.17 ± 0.05^{a}	2.24 ± 0.02^{d}	2.56 ± 0.27^{e}	1.94 ± 0.03^{c}
Carotenoïds (mg/100g)	9.12 ± 0.34^{c}	7.111 ± 0.61^{a}	6.86 ± 0.03^{a}	7.202 ± 0.54^{a}	5.05 ± 0.07^{b}
Ash (g/100g)	1.29 ± 0.07^{ab}	1.15 ± 0.06^{b}	1.52 ± 0.01^{a}	1.45 ± 0.20^{a}	1.44 ± 0.21^{a}

The values presented in the table are an average of 3 independent analyzes ± standard deviation. The letters (a-e) in the same column of the table indicate significant differences ($P < 0.05$, Fisher's LSD test).

Table 3. Minerals composition of *Saba senegalensis* from five geographical areas of Senegal.

Minerals (mg/100g)	**Bayla**	**Niamone**	**Youtou**	**Bandafasse**	**Salémata**
Ca	183	1279	633	113	435
K	177	174	151	218	158
Na	23	1	6	10	0,8
Mg	30	25	24	30	25
P	9	13	9	13	13
Fe	1	1.7	0.9	1	1

However, the position on the Dim 2 axis contrasts fruits with a content of polyphenols and ashes (Salemata and Niamone), fruits with low levels of citric acid, fructose and vitamin C (Bayla). Thus, the fruits of ***Saba senegalensis*** have been grouped into three classes. The first class consists of fruits from Bandafasse. Class 2 consists of fruits from Niamone and Salemata. Finally, class 3 consists of fruits collected at Youtou and Bayla. (Figure 1 & Figure 2)

3.3. Discussion

Average pH values between 2.72 and 2.85 give the fruit an acidic character. These pH values are slightly higher than 2.24 found by [15]. These pH values are

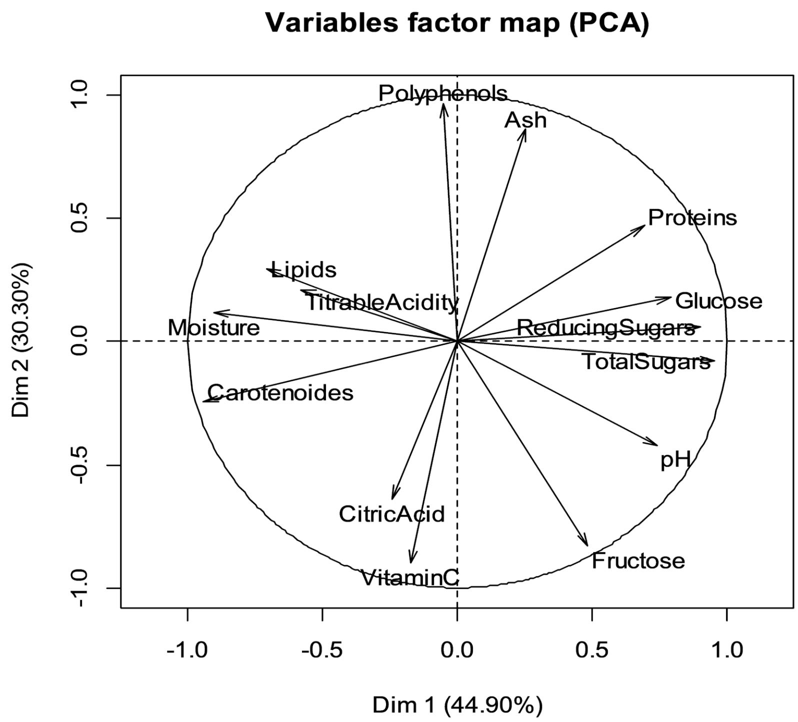

Figure 1. Circle of correlation between the physicochemical and biochemical characteristics of *Saba senegalensis* fruits and the first two dimensions of PCA.

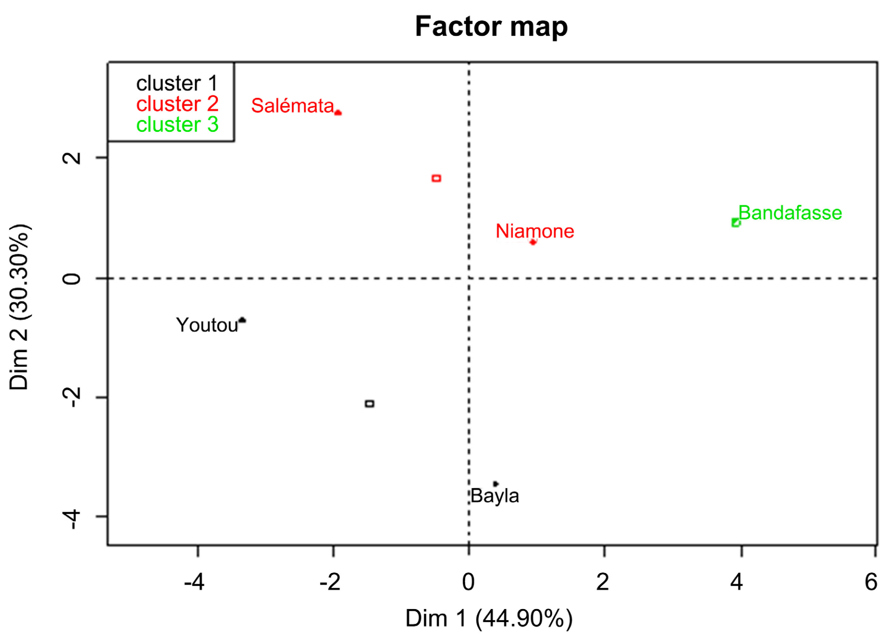

Figure 2. Distribution of collection areas according to the physicochemical and biochemical characteristics of *Saba senegalensis* fruits in the PCA factorial plane.

correctly correlate with the high levels of total and citric acidity which respectively vary between (37.80 and 69.80 mEq/100g) and (2.33 to 1.85 g/100g). These later values are close to that found by [9] whose titratable acidity value was 30.44 mEq·100g^{-1}. Compared to other locally sourced local fruits, the fruit of *Saba se-*

negalensis seems more acidic than *Detarium senegalensis* with a pH of 3.51 and 23 - 45 mEq·$100g^{-1}$ of titratable acid [16] and *Sclerocarya birrea* with a pH of 3.66 - 3.95 and a titratable acidity of 15.1 - 19.9 mEq·$100g^{-1}$ [17]; it is less acidic than baobab (*Adansonia digitata*) fruits with a pH of 1.89 and acidity of 97 - 144 mEq·$100g^{-1}$ [13]. The combined low pH and high acidity gives the fruit of *Saba senegalensis* a very good aptitude for conservation and thus a great advantage for technological issues. The value of crude protein (0.282 g·$100g^{-1}$) is lower than that found by [8] [9] which were respectively 0.8% and 0.3%. The weakness of Saba fruit in lipid (0.96 to 1.66 g/$100g^{-1}$) and protein (0.21 to 0.24 g/$100g^{-1}$), seem to be characteristic of fruits. Concerning the vitamin C contents of the Saba fruits, they are between 32.86 and 198.22 mg/100g. The zones of the Casamance region stand out; Bayla, Youtou, Niamone are the zones giving the richest fruits in ascorbic acid (198.22, 154, 96 and 145.59 respectively) whereas those of Kédougou give the weakest namely Salemata and Bandafasse with respective values of 32.86 and 58.45 mg/100g. The sampling area may affect the vitamin C content of the fruits. Indeed, these first three zones share the same climatic conditions. Significant differences between samples are likely due to ecological conditions. These vitamin C contents are higher than results indicated by [7] which were between 34.8 and 67.5 mg·$100g^{-1}$ [9]: 16 mg·$100g^{-1}$. The vitamin C content of *Saba senegalensis* is lower than that of *Detarium senegalensis* (1200 to 2200 mg·$100g^{-1}$), *A. digitata* (125 to 312 mg·$100g^{-1}$) [13] and *Ficus gnaphalocarpa* (487 mg·$100g^{-1}$) [18]. However, the vitamin C content of the samples studied is higher than those established for other fruits which all vary between 1.42 and 3.9 mg·$100g^{-1}$ such as tamarind, soursop, pineapple, fruit passion, mango [20], and *Sclerocarya birrea* 16.44 mg/100g [17]. Carotenoids are responsible for the orange-yellow coloring of fruits. In this study, the fruits of the Youtou and Bayla localities showed a great variability of carotenoid contents with extreme values of 1.13 and 2.47 mg·$100g^{-1}$, respectively. The impact of pedoclimatic conditions, stage of maturity at harvest and storage conditions of fruits are all factors that may explain these variations. These values show us that Saba fruits are good sources of carotenoids. Polyphenols exhibit antioxidant, antiviral, anti-inflammatory and anti-cancer activities [19]. Although variable, the levels of polyphenols found during this study (1.17 - 2.56 g·$100g^{-1}$) are slightly higher than that indicated by [7] which was 0.94 g·$100g^{-1}$, However, these values are comparable to those of *A. digitata* (2.5 g·$100g^{-1}$) fruits of *Hibiscus sabdarifa* (1.34 - 3.73 g) [13]. They are higher than those found for mango (68 mg·$100g^{-1}$), banana (51 mg·$100g^{-1}$), pineapple 47 mg·$100g^{-1}$) [20], apple (180 mg EAG/100g) [21]. Water is the main constituent of the fruit of *S. senegalensis* with an average value of 74.77 g·$100g^{-1}$. This value is lower than that found by [15] (80 g·$100g^{-1}$), but it is well above the value of [9] (48 g·$100g^{-1}$). On the other hand, it is comparable to several fruits such as *Detarium senegalensis* and Cucurbita which have respective values of 62.59% [16] and 75.54% [22]. Amount of water explains the perishable nature of the fruit. The total sugars of Saba are mainly composed of reducing sugars which is closed to 88% of the total sugar quantity. The reducing sugars are essentially composed of glucose (3.19 and 3.66 g·$100g^{-1}$) and fructose (1.76 to 3.52 g·$100g^{-1}$). This profile in simple carbohydrate remains a handicap for the conservation of the fruit while facilitating the fermentation.

The total mineral content of the pulp of *S. senegalensis* varies between 1.52 and 1.15 g·$100g^{-1}$. This value is lower than that found by [9] which is 2.8 g·$100g^{-1}$. The pulp is rich in mineral compounds (P, Mg and Fe). As in most fruits, potassium and calcium predominate and sodium is almost non-existent.

4. Conclusion

The analysis of *Saba* fruits collected in the main production areas confirmed the acidity of the fruit due mainly to citric acid and showed a high content of polyphenols, ascorbic acid and carotenoids. The Casamance area offers fruit richer in vitamin C. Nevertheless, a thorough study of the functional molecules should be carried out as the different profiles of polyphenols, and carotenoids as well as the antioxidant activity. The aromatic profile will also be very useful to better evaluate the potential of this highly appreciated fruit.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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