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Nutritional Potential of *Parkia biglobosa* Fruits Pulp Harvested in Senegal

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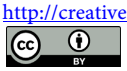

Abstract

Parkia biglobosa is a non-wood forest product whose resources are used in food and pharmacopoeia. The pulp has interesting nutritional qualities. African locust bean fruits harvested in Senegal are characterised by low moisture (9.78% to 12.31%), which is crucial for long storage. The pulp is slightly acidic (pH = 4.84 to 5.16). It is also very rich in sugar, with a minimum concentration of 30.8g/100g, and is mainly made up of reducing sugars. Carotenoids are abundant in the pulp (on average 16.75 mg/100 g) and β-carotene is the main carotenoid. As for minerals, K and Mg are the most abundant, with average concentrations of 451.33 mg/100 g and 300.67 mg/100 g respectively. In addition, heavy metals such as arsenic, lead and cadmium are below the detection threshold (<0.002 mg/100 g) and are present in the pulp at a concentration below the standard set by the Codex Alimentarius. The organic acid profile was also determined, showing that citric acid (average 1131.88 mg/100 g) is the predominant organic acid in the pulp. Principal component analysis (PCA) revealed that the pulp of Parkia fruits harvested in Senegal was homogeneous in terms of physico-chemical and biochemical characteristics, despite a few differences.

Keywords

Parkia biglobosa, Fruit, Pulp, Physico-Chemical and Biochemical Characteristics

1. Introduction

Parkia biglobosa (PB), also known as African locust bean, is a deciduous tree

reaching heights of 20 m [1]. It is also endemic to the Sudanian savannahs of West Africa. In Senegal, the African locust bean is found mainly in three localities: Casamance, Kaolack and Thiès [2]-[4]. *Parkia biglobosa* provides resources that are used for food and therapeutic purposes. After fermentation, the seeds are used as a flavour enhancer in many preparations, and the pulp is usually consumed directly [5]-[7]. In addition, the pulp, seeds and leaves are used in traditional pharmacopoeia to treat a number of diseases [8]-[10]. Work has been carried out on the physico-chemical characterisation of African locust bean seed and pulp [11]-[13]. This research has shown that African locust bean pulp has interesting nutritional qualities. The aim of this study is to extend the literature on the physico-chemical and biochemical properties of *Parkia biglobosa* pulp. Certain parameters have not yet been determined for the pulp. In addition, no research has been carried out on the characteristics of the pulp of fruits harvested in Senegal, as it should be noted that soil conditions can influence the physico-chemical parameters of pulp [14]. Extensive knowledge of the physico-chemical and biochemical properties of pulp will enable us to highlight the nutritional potential of pulp and explore ways of using pulp in the food industry.

2. Materials and Methods

2.1. Collection and Sampling

Parkia biglobosa (PB) fruits were collected in June 2023 from three main African locust bean production areas in Senegal: Thiès (14˚45'36.0 'N 16˚48'00.0 'W), Kaolack (14˚09'57.3 'N 16°04'34.2 'W) and Casamance (12˚42'34.1 'N 15˚34'18.4 'W). Fruits at the same stage of ripening (brown pod) were selected in each zone. They were shelled and transformed into pulp manually. The pulp thus obtained was packed in airtight packaging. The various constituents of the pulp were analysed using triplicate analytical methods.

2.2. Macronutrients

Macronutrient analysis is carried out in accordance with the protocols described by AFNOR standards. The water content is determined by dehydrating the seeds coated with the pulp after hulling (Standard NF V 03-707) [15]. Total minerals are determined by incinerating the pulp at 550˚C for 3 hours (Standard V76-101) [16]. The Kjeldahl method (standard NF 03-050) [17] was used to determine the nitrogen content and then the protein content by multiplying the total nitrogen concentration by 5.7 as a coefficient. Titratable acidity and pH were analysed using standard NF V 05-101.

2.3. Micronutrients

To determine the organic acid profile, the extract of PB pulp must be prepared [18]. A test sample of 0.1 g of pulp is mixed with 1.5 mL of acidified water (0.002 M H_2SO_4) at 70˚C. Extraction was initiated in an ultrasonic tank at 70˚C for 15 minutes and the mixture was stirred for 2 hours. Centrifugation and microfiltration

(0.45 µm) produced an extract ready for injection (10 µL). The Thermo Fisher Scientific Dionex ICS-5000, equipped with a Thermo Scientific Ion Pack AS11-HC 4 mm × 250 mm column, a 4 mm AERS pump and a conductivity detector, was used with a KOH gradient concentration of 1.25 mM to 55 mM in 50 min and a solvent flow rate of 1 mL/min [19]. The sugar profile was obtained by liquid chromatography using the same extraction method as for organic acids [18]. The electrochemical detector of the type Thermo Fisher Scientific Dionex ICS-5000 was necessary for the determination of the profile [19]. The ethanol/hexane solvent was used to extract the carotenoids from the pulp in an alkaline medium ($MgCO_3$). The mixture was filtered under vacuum (sintered pore size 2) and the residue was washed with the solvent. The organic phase (consisting of carotenoids) was separated from the filtrate using a separating funnel and washed with sodium chloride and distilled water. The hexane phase was evaporated to dryness under vacuum at 40˚C. The carotenoids were recovered in methanol (80/20) before analysis by HPLC [20]. Polyphenols were determined using the Follin-Ciocalteu reagent according to the method described by *Georgé et al.* In addition, the Niton XLT900s spectrometer was used to determine the mineral composition of the pulp. The instrument is equipped with a silver anode as an excitation source and a detector fitted with several filters, each of which measures the concentration of the targeted minerals [21].

2.4. Statistical analysis

STATISTICA version 7.1 software was used to perform the one-factor analysis of variance. Using the LSD Fisher test, statistical differences with a probability value of less than 5% ($p < 0.05$) are considered significant. In addition, principal component analysis (PCA) was performed on the physico-chemical and biochemical data using XLSTAT software version 2021.2.2. It was used to determine the best correlations between the random variables.

3. Results

The results of the physico-chemical analyses are given in Table 1.

Table 1. Physico-chemical characteristics of *Parkia biglobosa* pulp.

		Parkia biglobosa pulp			
Parameters	Units	**Thiès**	**Kaolack**	**Casamance**	**Mean concentration**
Moisture	%	12.31 ± 0.05^{c}	10.95 ± 0.69^{b}	9.78 ± 0.60^{a}	11.01
pH		5.00 ± 0.01^{b}	4.84 ± 0.02^{a}	5.16 ± 0.01^{c}	5.00
Titratable acidity	mEq/100 g	13.09 ± 0.39^{a}	17.72 ± 0.42^{b}	12.61 ± 0.03^{a}	12.61
Protein	g/100 g	4.29 ± 0.46^{a}	4.03 ± 0.00^{a}	4.03 ± 0.00^{a}	4.12
Ash	%	3.44 ± 0.15^{b}	2.89 ± 0.01^{a}	2.84 ± 0.06^{a}	3.06
Total sugars	g/100 g	31.30 ± 0.71^{a}	34.45 ± 0.24^{b}	30.80 ± 0.00^{a}	32.63
Reducing sugars	g/100 g	23.39 ± 0.18^{b}	32.54 ± 0.25^{c}	22.08 ± 0.07^{a}	26.00

Continued

Glucose	mg/100 g	39.30 ± 9.81[a]	29.20 ± 12.12[a]	45.72 ± 13.17[a]	38.07
Fructose	mg/100 g	37.55 ± 16.43[b]	26.07 ± 10.84[a]	48.74 ± 16.30[b]	37.45
Sucrose	mg/100 g	18.92 ± 3.20[b]	1.76 ± 0.64[a]	31.19 ± 5.84[b]	17.29
Polyphenols	mg/100 g	241.00 ± 31.70[a]	391.02 ± 34.96[b]	201.86 ± 17.62[a]	277.96
Carotenoids	mg/100 g	15.69 ± 0.60[a]	14.47 ± 4.71[a]	20.10 ± 6.32[a]	16.75

Statistical analysis shows a significant difference in moisture content, pH and titratable acidity. Moisture content varied from 9.78% (Casamance) to 12.31% (Thiès), pH from 4.84 (Kaolack) to 5.16 (Casamance) and acidity from 12.61 mEq/100 g (Casamance) to 17.72 mEq/100 g (Kaolack). With regard to total minerals, there was no significant difference between samples from Kaolack (2.89%) and Casamance (2.84%). *Parkia* fruit harvested in Thiès had a much higher concentration of total minerals (3.44%). The pulp of fruit harvested in Kaolack (34.45 g/100 g) had a higher total sugar content than fruit harvested in Thiès (31.30 g/100 g) and Casamance (30.80 g/100 g). Reducing sugars varied from 22.08 g/100 g in Casamance to 32.54 g/100 g in Kaolack. Analysis of the sugar profile shows variations in fructose and sucrose content. The fructose and sucrose contents varied respectively from 26.07 mg/100 g (Kaolack) to 48.74 mg/100 g (Casamance) and from 1.76 mg/100 g (Kaolack) to 31.19 mg/100 g (Casamance). However, there was no significant difference in glucose content. The average value to be considered is 38.07 mg/100 g. Only the pulp of fruit harvested in the Kaolack region had a glucose content (29.2 mg/100 g) below the average. The origin of the samples had no impact on the protein content of the pulp. The pulp of fruit harvested in Senegal has an average protein concentration of 4.12 g/100 g. In terms of pigments, there was no significant difference in carotenoid concentration, with an average value of 16.75 mg/100 g. Only the Casamance sample had a higher than average carotenoid concentration (20.10 mg/100 g). Unlike carotenoids, there was a variation in polyphenol content. This fell from 391.02 mg/100 g (Kaolack) to 201.86 mg/100 g (Casamance).

As for the organic acid profile (Table 2), there was no variability in the concentrations of lactic acid, acetic acid, malic acid and citric acid. On average, the concentrations of lactic acid, acetic acid, malic acid and citric acid are equivalent to 333.96 mg/100 g, 194.49 mg/100 g, 153.75 mg/100 g and 1131.91 mg/100 g respectively. However, the concentrations of formic acid, tartaric acid, oxalic acid and iso-citric acid are variable. Indeed, the pulp of fruit harvested in Kaolack has higher concentrations of formic acid (40.06 mg/100 g), tartaric acid (53.50 mg/100 g) and iso-citric acid (248.06 mg/100 g) than in other localities. In addition, the pulp of fruit harvested in Thiès has a higher concentration of oxalic acid (216.19 mg/100 g) than in other areas. Table 3 shows the mineral composition of PB pulp. It shows that calcium, potassium, magnesium and phosphorus are the minerals most present in the pulp regardless of locality. These minerals, with the exception

of P, are more abundant in the pulp of fruit harvested in Thiès, with Ca, K, Mg and P concentrations of 88.6 mg/100 g, 475 mg/100 g, 316.7 mg/100 g and 61.2 mg/100 g respectively. Analysis of heavy metals (As, Cd, Cu, Mn, Pb, Se and Zn) shows that they are present in low concentrations. Manganese, the most representative of the heavy metals mentioned, has an average concentration in the PB pulp of 7.17 mg/100 g. Pb, As and Cd are below the detection threshold (<0.002 mg/100 g).

Table 2. Organic acid profile of *Parkia biglobosa* fruit pulp.

	Parkia biglobosa pulp			
Organic acids (mg/100 g)	**Thiès**	**Kaolack**	**Casamance**	**Mean concentration**
Lactic acid	299.50 ± 30.48[a]	341.68 ± 83.93[a]	360.71 ± 49.14[a]	333.96
Acetic acid	139.60 ± 4.95[a]	269.82 ± 17.25[a]	174.04 ± 38.68[a]	194.49
Formic acid	22.76 ± 12.30[a,b]	40.06 ± 4.81[b]	26.86 ± 17.75[a]	29.89
Malic acid	57.03 ± 4.74[a]	202.75 ± 92.42[a]	201.47 ±15.91[a]	153.75
Tartaric acid	48.44 ± 3.82[a]	53.50 ± 2.55[b]	46.22 ± 3.32[a]	49.39
Oxalic acid	216.19 ± 15.91[b]	180.39 ± 20.29[a]	207.44 ± 16.83[a,b]	201.34
Citric acid	720.10 ± 57.84[a]	1300.06 ± 83.14[a]	1375.58 ± 64.31[a]	1131.91
Iso-citric acid	108.26 ± 1.48[a,b]	248.06 ± 62.79[b]	200.77 ± 10.93[a]	185.70

Table 3. Mineral composition of *Parkia biglobosa* pulp.

Minerals (mg/100 g)	**Thiès**	**Kaolack**	**Casamance**	**Mean concentration**
Ca	88.60	78.80	62.00	76.47
K	475.00	458.10	420.90	451.33
Mg	316.70	314.60	270.70	300.67
P	61.20	63.60	49.10	57.97
Fe	0.70	0.70	0.60	0.67
Mn	8.80	6.00	6.70	7.17
Cu	0.30	0.40	0.30	0.33
Zn	0.30	0.30	0.30	0.30
Se	0.21	0.21	0.22	0.21
Co	0.30	0.30	0.31	0.30
Mo	0.20	0.21	0.21	0.21
Pb	<0.002	<0.002	<0.002	<0.002
Cd	<0.002	<0.002	<0.002	<0.002
As	<0.002	<0.002	<0.002	<0.002

Principal Component Analysis

The correlation graph (Figure 1) between certain physico-chemical parameters of PB fruit pulps harvested in Senegal was established using principal component analysis (PCA). A variability of 100% was obtained with the two factorial axes Dim1 and Dim2. This means that the representation is of good quality. PCA was also used to study the effect of origin on the physico-chemical characteristics of African carob pulp. Analysis of Figure 1 shows that moisture is positively related to ash and protein. Reducing sugars and total sugars are positively correlated. However, pH and titratable acidity are negatively correlated. Concerning the correlation between the axes the variables glucose, fructose, sucrose, carotenoids and pH were positively correlated with the first Dim1 axis, while the other variables total sugars, reducing sugars, titratable acidity and polyphenols were negatively correlated. The parameters used for sweet taste, acidity and colour are well represented on this first Dim1 axis, which can therefore be considered the organoleptic axis. On the second Dim2 axis, the variables ash, moisture and protein were positively correlated with the axis. However, no variable was negatively correlated with the Dim2 axis. The Dim2 axis can be considered as the nutritional axis. This correlation graph highlights the difference between the physico-chemical characteristics of PB pulps. Indeed, the Dim1 axis shows that the pulp of fruit harvested in Casamance is richer in glucose, fructose, sucrose and carotenoids and has a higher pH value, whereas on the same axis, the pulp of fruit harvested in Kaolack has a higher content of total sugars, reducing sugars, polyphenols and titratable acidity. On the other hand, on the Dim2 axis, the pulp of fruit harvested in Thiès had a higher moisture and ash content. Despite these differences in physico-chemical parameters, the PB fruits harvested in Senegal were grouped together in a single class, showing a degree of homogeneity (Figure 2).

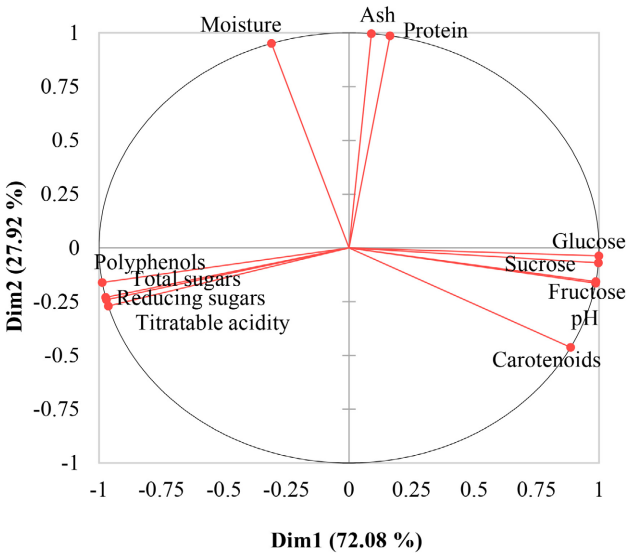

Figure 1. Correlation circle for the physico-chemical and biochemical characteristics of PB fruit pulp.

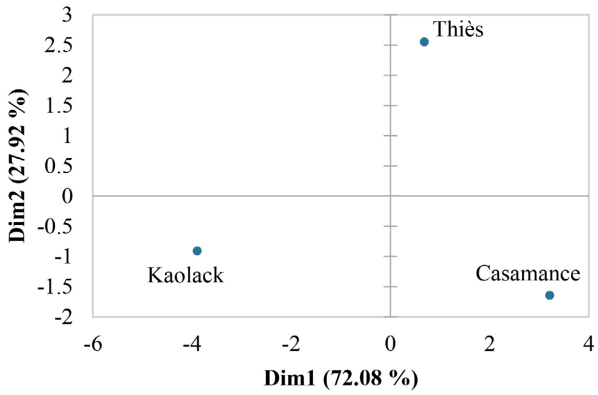

Figure 2. Distribution of collection areas according to the physico-chemical and biochemical characteristics of PB fruit in the PCA factorial design.

4. Discussion

PB pulp has a low moisture content compared with *Mangifera indica L.* (83.39% ± 0.27%) [22] and *Saba senegalensis* (86.5% ± 4.25%) [23]. Unlike these two fruits, the low moisture content of PB fruit ensures its long shelf life. In this study, the moisture values are close to those of [24] [25] which, after analysis, show that the moisture content of *Parkia* fruit is between 11.3% and 15.83%. The pH results indicate that the fruit is slightly acidic. This is confirmed by the titratable acidity values. Indeed, local fruits such as *Adansonia digitata L.*, *Saba senegalensis*, *Hibiscus sabdariffa L.* and *Detarium senegalensis* are more acidic with pH values of 3.21 [26], 2.85 [23], 2.42 [27] and 3.51 [28] respectively. This low acidity can be a disadvantage when it comes to preserving processed African locust bean products. [13] found a total mineral content of 2.69% ± 0.2%, which is close to the values found in this study. With regard to the mineral composition of *Parkia biglobosa* pulp, [11] showed that the calcium content in mg/100 g ranged from 0.21 to 1087.1 and those for potassium and phosphorus from 1.056 to 1670 mg/100 g and 0.014 to 640.1 mg/100 g respectively. The results of [11] confirm the Ca, K and P concentration values obtained in this study. On average, the magnesium concentration of 300.67 mg/100 g is close to that found by [25] (225.15 ± 85.56 mg/100 g). In this study, the iron concentration was much lower than those found by [29], which found iron concentrations of between 2.98 and 3.18 mg/100 g. Soil conditions may explain this difference. Total sugars averaged 32.18 g/100 g. The authors [30] found a concentration in PB pulp equal to 30.35 g/100 g. Compared with *Adansonia digitata L.* pulp (57.27 g/100 g) [30], PB pulp has a lower concentration of total sugars. Reducing sugars are more abundant, accounting for over 70%. The average glucose content (38.07 mg/100 g) is similar to that of fructose (37.45 mg/100 g). The sucrose content, on the other hand, is lower, with an average value of 17.29 mg/100 g. On average, the protein content of the pulp is 4.12 g/100 g, a value similar to that found by [31] (4.129 ± 0.328 g/100 g). With regard to pigments, [32] found a polyphenol concentration equal to 200 mg/100 g, a value close to that found in the pulp of samples harvested in Thiès (201.86 mg/100 g) and Ziguinchor (241.00 mg/100 g). The results of the [11] study show that carotenoids

are present in the pulp at a concentration of 10.463 mg/100 g. After analysis, the samples harvested in Senegal have a higher carotenoid content than [11]. PB pulp is mainly rich in β-carotene, a precursor of vitamin A [33]. In view of the results obtained, PB pulp is a good source of carotenoids. In fact, it is richer in carotenoids than mango puree and watermelon, whose maximum contents found by [34] [35] in their work are 5.81 mg/100 g and 5 mg/100 g. [36] found citric acid and formic acid concentrations equal to 125.89 mg/100 g and 62.04 mg/100 g respectively. In this study, the concentration of citric acid found was much higher and that of formic acid lower than the values found by [36]. Compared with the citric acid and malic acid concentrations of *Citrus limon* [37], those of PB pulp are much lower. Heavy metals must be present in reasonable concentrations to avoid any risk to consumers. According to codex alimentarius standard STAN 193-1995 [38], the concentration of arsenic in many food products must be between 0.001 and 0.05 mg/100 g. This standard also sets maximum Cd (0.01 mg/100 g) and Pb (0.01 mg/100 g) concentrations in legumes such as *Parkia biglobosa*. Based on the results obtained, PB pulps have arsenic, lead and cadmium concentrations (<0.002 mg/100 g) below the values set by the standard. On the basis of these data, PB pulp harvested in Senegal can be consumed without risk.

5. Conclusion

The pulp of *Parkia biglobosa* fruits harvested in Senegal has superior nutritional qualities. It has a high concentration of sugar and carotenoids. Analysis of the minerals reveals that the concentration of heavy metals is below the standard set by the Codex Alimentarius. Principal component analysis (PCA) shows that the physico-chemical and biochemical data for the pulp of carob fruits harvested in Senegal are homogeneous. With a view to the future, the amino acid profile needs to be determined and the potential uses of carob pulp in the agri-food sector investigated.

Conflicts of Interest

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

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