Vol. 15(1) pp. 26-32, January 2021
DOI: 10.5897/AJFS2020.2010
Article Number: B8E424165801
ISSN: 1996-0794

http://www.academicjournals.org/AJFS

African Journal of Food Science

Full Length Research Paper

Comparison of chemical composition of fruit pulp of *Parkia biglobosa* (Jacq.) Benth from differents ecoregions

Dao Aboubacar Sidiki[1,2*], Parkouda Charles[1], Traoré MA Esther[1], Aimée WDB Guissou[1], Barbara Vinceti[3], Céline Termote[4], Mattia Manica[5] and Bassolé Imael Henri Nestor[2]

[1]Centre National de la Recherche Scientifique et Technologique, Institut de Recherche en Sciences Appliquées et Technologies, Département Technologie Alimentaire, 03 BP 7047, Ouagadougou 03, Burkina Faso.
[2]Laboratoire de Biologie Moléculaire, d'Epidémiologie et de Surveillance des agents Transmissibles par l'eau et les Aliments, Université Joseph, Ki-Zerbo, 03 BP 7021 Ouagadougou 03, Burkina Faso.
[3]Alliance Bioversity-CIAT, Rome, Italy.
[4]Alliance Bioversity-CIAT, Nairobi, Kenya.
[5]Department of Biodiversity and Molecular Ecology, Research and Innovation Centre, Fondazione Edmund Mach, San Michele all'Adige, Italy.

Received 26 August, 2020; Accepted 27 October, 2020

***Parkia biglobosa* (Jacq.) Benth commonly called néré in French-speaking Africa is a semi-domesticated indigenous tree with a multi-purpose and highly appreciated use. Its pod-shaped fruits contain a yellowish floury pulp, eaten raw or used to make drinks, couscous and for raw or cooked dough. The objective of this study was to determine the profiles of minerals (Fe, K, Mg, Zn, Ca), beta-carotene, protein, ash, lipid and total sugar content as well as pH and acidity of the pulps from three ecoregions of Burkina Faso. The results showed quantitative difference in the composition of *Parkia biglobosa* (Jacq.) Benth pulp from the different ecoregions. Pulp from tree of South Sahelian zone contained the highest concentration of beta-carotene and carbohydrates (530.52±68.11 µg/100g; 64.96±8.9% DW, respectively). Whereas, the North Sudanian zone exceeded the others ecoregion in terms of K (3 301.25±872.85 mg/100 g DW); Mg (257.63±90.15 mg/100 g DW); Zn (1.28±0.37 mg/100 g DW); Ca (519.41±591.13 mg/100g DW) and protein (3.76±0.39 g/100 g DW). The South Sudanian zone displays the highest content in Fe (1.92±1.37 mg/100 g DW). As for the equivalent citric acid quantified in this study, the North Sudanian zone had the highest concentrations (0.96 ± 0.18 g/100 g DW) in the pulp. The observed variation has implications regarding the use of these data in food and nutrition programs, and in selecting sources of planting material for reforestation initiatives and agroforestry systems.**

Key words: *Parkia biglobosa* (Jacq.) Benth pulp, nutritional composition, physicochemical characteristics, ecoregions.

INTRODUCTION

Parkia biglobosa (Jacq.) Benth., also locally called Néré, is a valuable multipurpose tree species found in the Sudanese savannahs, providing food, medicines and fodder for local inhabitants (Teklehaimanot, 2004). The tree is normally spared from cutting, when the land is cleared for agriculture (Thiombiano et al., 2013). One of the aspects for which *P. biglobosa* is appreciated is the high nutritional content of its fruits (pods). The edible parts of the pods (pulp and seeds) are used as ingredients in different foods and are subjects of study aimed at improving the nutritional quality of derived products. To date, the seeds of *P. biglobosa* have received most attention in study on nutrition and on modalities of consumption, as they are used to produce a highly appreciated and widely consumed alkaline fermented condiment, known as ‘soumbala’ or ‘dawadawa’, according to the local terminology (Ouoba et al., 2004). Besides of seeds, the pulp (a yellow powder) is largely consumed, usually raw, by collectors (such as shepherds and passers-by), or used for the preparation of drinks, cakes and/or paste (raw or fried), after mixing with water (Ouédraogo, 1995). The pulp can also be stored for use during the lean period (Thiombiano et al., 2014). So far, several of the studies have been carried out to characterize the chemical composition of the pulp.

These results showed great variation, as also highlighted in the study reported by Stadlmayer et al. (2013) on under-utilized fruits. However, little or no information is known about the chemical characteristics of pulp from different ecoregions of Burkina Faso where the role of the pulp in combating food scarcity and nutritional deficiencies has also been demonstrated. Till now, no studies have been undertaken to assess the variation in the nutrient content of pulp between and within Parkia populations.

The aim of the present study was to compare the nutritional composition and physical characteristics of the pulp of *Parkia biglobosa* (Jacq.) Benth trees located in three different ecoregions with different precipitation gradients and soil characteristics. This will provide the community with data that can be used in food and nutrition programs, as well as in the selection of tree planting material for the restoration of forest landscapes and the establishment of agroforestry systems.

MATERIALS AND METHODS

Study sites

The study was conducted in the South Sahelian Ecoregion (SSE) (14°-15°54’ N), North Soudanian Ecoregion (NSuE) (11°30'- 14° N) and South Soudanian Ecoregion (SSuE) (9°-11°30' N) (MECV 2007) in Burkina Faso. The three zones are characterized by a dry tropical climate with a unimodal rainy season that lasts from May to October (Somé and Sivakumar, 1994; Somé and Sia, 1997). The soil is arid brown in the SSE, indurated leached tropical ferruginous and weakly desaturated ferralitic in the SSuE, and eutrophic tropical brown, leaching tropical ferruginous spotted and concreted, and leaching indurated tropical ferruginous in the NSuE (Pallo et al., 2009).

Sample collection

The pods at mature stage (dry and brown) were collected from at least 20 trees in each ecoregion between April and May 2017. The shell was manually removed from the pods then the pulp was separated from the seed. The pulp samples (100 to 300 g) were transported to the lab, packaged in plastic bags, placed in opaque plastic pots, properly labelled and then stored in the freezer.

Analysis methods

The moisture, ash, protein and fat contents as well as pH and citric acid content were carried out using the official methods of the AOAC methods (AOAC, 2005). The total sugar content was estimated using a colorimetric method (Montreuil and Spik, 1969). The mineral content (Fe, Zn, Mg, K and Ca) was determined using an atomic absorption spectrophotometer, following the manufacturer's recommendations (Thermo Scientific AA ICE 3000).

The content of β-carotene in *Parkia biglobasa* pulp was determined using high performance liquid chromatography (HPLC) as described by Somé et al. (2004). The standard solution was prepared by diluting a small amount of the β-carotene standard in 3 ml of hexane to produce the stock solution. The stock solution thus obtained was diluted 1:10, 1:100 and 1:1000. The optical densities of the diluted solutions were read at 450 nm with the spectrophotometer (CECIL UV-Visible 160-A; United Kingdom). The concentrations of the standard were calculated from the optical densities obtained. The β- carotene in the samples was extracted by weighing 10 mg of dry pulp powder to which 1 ml ethanol and 4 ml hexane were added. After stirring with a vortex for 2 min, the preparation was then stored at 4°C for 12 to 15 h in the refrigerator. After bringing to room temperature, 1 ml of a NaCl solution (3M) is added to the preparation. After stirring, the mixture is centrifuged at 3000 rpm for 5 min at 5°C. The supernatant consisting of the hexanic phase is removed and transferred to another tube. Then 3 ml of hexane was added to the pellet, followed by shaking and centrifugation; the supernatant was removed again and added to the first supernatant. This operation is repeated a third time. 1 ml of the extract is then taken for evaporation under a nitrogen jet, and the dry extract thus obtained is recovered in 1 ml of acetonitrile. The standard solutions are injected into the HPLC apparatus and the peak area recorded. Then sixty (60) µl of the extract recovered in acetonitrile after microfiltration is injected. The peaks thus obtained will be used to calculate the content of β-carotene. The HPLC chain used consists of a JASCO PU 980 pump, a JASCO 975 UV/Visible detector, a C-18 Supelcosil column (Bellefonte, USA), 25 cm long and 4.6 mm in diameter. The mobile phase consists of acetonitrile, dichloromethane and methanol in proportions of 70, 20 and 10%, respectively.

Data analysis

The analyses were performed in triplicates. The data were subjected to analysis of variance (ANOVA) using XLSTAT software,

*Corresponding author. E-mail: daoabou2000@gmail.com. Tel: +226 76478185.

Table 1. Proximate composition (excluding fibers), nutritional composition and physical characteristics of *Parkia biglobosa (Jacq.) Benth* pulp from 3 ecoregions.

Number of samples	SSE	NSuE	SSuE	Mean	P value
	25	20	20		
Moisture (%)	15.79± 3.33^{a}	12.68± 1.22^{b}	12.65± 0.56^{b}	13.87±2.65	< 0.0001
Carbohydrates (g/100 g DW)	64.96±8.9^{a}	61.38±3.81 ^{a}	63.51±4.15^{a}	63.41±6.43	0.18
Protein (g/100 g DW)	3.62±0.91^{a}	3.76±0.39^{a}	3.41±0.66^{a}	3.6±0.71	0.290^{a}
Ash (g/100g DW)	3.77±0.69^{a}	4.16±0.58^{a}	3.07±0.66^{b}	3.67±0.77	< 0.0001
Lipids (g/100 g DW)	0.48±0.2^{b}	1.04±0.91^{a}	0.66±0.25^{ab}	0.71±0.58	0.004
Fe (mg/100 g DW)	1.47± 0.64a	1.43±0.4^{a}	1.92±1.37a	1.6±0.9	0.147
K (mg/100 g DW)	1 898.32±390.22^{b}	3 301.25±872.85^{a}	1 657.38±338.78^{b}	2 255.86±905.94	< 0.0001
Mg (mg/100 g DW)	219.99±83.98a	257.63±90.15^{a}	199.13±75.94^{a}	225.15±85.56	0.088
Zn (mg/100 g DW)	0.87±.0.21b	1.28±0.37^{a}	0.92±0.37^{b}	1.01±0.36	0
Ca (mg/100 g DW)	407.93± 214.61^{ab}	519.41±458.96^{a}	240.1±59.23^{b}	390.59±366.65	0.05
beta-carotene µg/100 g DW	530.52±68.11^{a}	460.85±68.9^{b}	431.86±53.15^{b}	478.72±76.3	< 0.0001
pH	5.43 ± 0.19^{a}	5.5 ± 0.15^{a}	5.47 ± 0.11^{a}	5.47 ± 0.16	0.369
Acidity (% Citric acid)	0.89 ± 0.27^{a}	0.96 ± 0.18^{a}	0.61 ± 0.15^{b}	0.82 ± 0.25	< 0.0001

Values are means ± standard deviation. Data from the same line in the same area followed by different letters are significantly different (p < 0.05).

version 2015.4.01.22368. The differences between the mean values were evaluated using the Tukey test at the significance level of $P < 0.05$. Principal Component Analysis (PCA) was performed using the package available in RStudio, version 1.1.463.

Calculation of the coverage of recommended daily intakes

$$\text{coverage of recommended daily intakes} = \frac{\textit{Nutrient content / 100 g of DW}}{\text{recommended daily intakes}} * 100$$

1 µg β-carotene = 0.167 µg Retinol Equivalent (RE) (FAO/WHO, 2001)

RESULTS AND DISCUSSION

The results of the pH and citric acid values of the pulp, according to locations, are presented in Table 1. The pH values varied from a lowest value of 5.43 ± 0.19 (SSE) to 5.5 ± 0.15 (NSuE). No significant difference was observed between the three sites. The pH values reported in the present study were higher than those (4.2) reported by Dahouenon-Ahoussi et al. (2012) on *P. biglobosa* pulp samples taken from markets in Benin.

With regard to the citric acid content, the SSuE samples presented the lowest citric acid content (0.61 ± 0.15 %), while the NSuE samples had the highest content (0,96 ± 0.18%). The equivalent citric acid values reported in the present study were lower than values (15.79%) reported by Dahouenon-Ahoussi et al. (2012). There was a significant difference between samples from the SSuE and those from the other two zones (P-value< 0.05), however the values in the samples from the SSE and NSuE were not significantly different.

Table 1 showed that the proximate composition of the pulp samples according to ecoregions. Pulp samples from the SSE had the highest moisture content (15.79 ± 3.33), while those from the SSuE had the lowest moisture content (12.65 ± 0.56). There was a significant difference between the moisture content of the samples from the SSE and the other two zones; however there was no significant difference between samples from the SSuE and the NSuE. The moisture content values reported in this study were lower than the values (23.54%) reported by Dahouenon-Ahoussi et al. (2012). However, they were similar to those reported by Kayalto et al. (2013) (13.20 ± 0.22) for the samples from Tchad.

Total sugar content ranged from 61.38 ± 3.81% (pulp from NSuE) to 64.96 ± 8.9% (pulp from SSE) with the mean of 63.41 ± 6.43% over all 3 locations. These values were similar to those reported by Kayalto et al. (2013) (65.82 ± 2.51) on samples from Tchad, and there was no significant difference in the sugar content of the samples from the three ecoregions.

The protein content ranged from 3.41 ± 0.66% (pulp from the SSuE) to 3.76 ±0.39% (pulp from the NSuE). The protein content reported by Kayalto et al. (2013) (4.59±0.22%) and by Makalao et al. (2015) (5.9 ± 0,00) were higher than those reported in this study. However, the protein contents of the present study were similar to those reported (3.4%) by Ouédraogo (1995).

The minimum and maximum percentage of ash detected was 3.07±0.66% (pulp from the SSuE) to 4.16 ± 0.58% (pulp from the NSuE) with an average of 3.67 ± 0.77%. There was a significant difference between the ashes content of the samples from the SSuE and the other two zones (SSE and NSuE), however there was no significant difference between the samples from the SSE

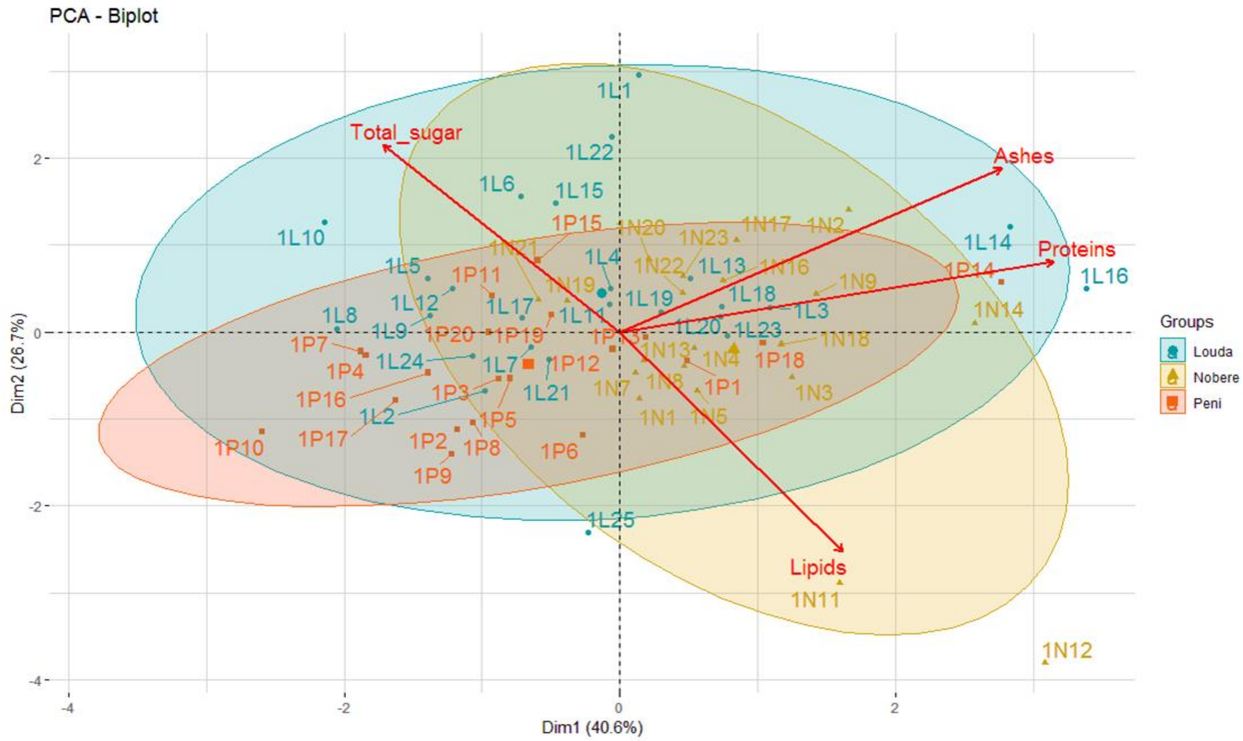

Figure 1. PCA-Biplot of the three selected populations of *Parkia biglobosa (Jacq.) Benth* based on the proximate composition of their pulp.

and the NSuE. The ash content reported by Kayalto et al. (2013) (5.17 ± 0.29%) and by Makalao et al. (2015) (8.28±0.1) were higher than those reported in this study.

Pulp samples from the South Sahel ecoregion had the lowest lipid content (0.48 ± 0.2), while those from the NSuE had the highest lipid content (1.04 ± 0.91). There was a significant difference between the lipid content of samples from the Southern Sahelian ecoregion and those from the Northern Sudanian ecoregion, but there was no significant difference between samples from the Southern Sudanese Zone and those from the other two zones. The lipid content values reported in this study were lower than the values reported by Kayalto et al. (2013) (2.49 ± 0.65%) and by Makalao et al. (2015) (2.04 ± 0.08%).

A PCA was applied to observe any possible clustering of tree individuals based on nutrient values. The scores of the first two principal components related to the total sugar, protein, ashes and lipid content for pulp from all 65 *Parkia biglobosa* trees from the three different localities (Figure 1). The first two principal components explained 67.3% of the total variation, with the first axis explaining 40.6% and the second axis 26.7% of the total variation, respectively. The Biplot PCA (Figure 1) showed that the clusters did not reflect a grouping by location. This indicates that in each locality based in a different ecoregion, trees present a broad range of values in nutrients and interesting nutritional characteristics. The Biplot PCA (Figure 1) shows that most samples in the SSuE (Peni) displayed macronutrients similar either to those of the SSE (Louda) or NSuE (Nobere).

Table 1 presented the micronutrients composition of the *P. biglobosa* pulp samples for each location. Fe content varied from 1.43 ± 0.64 mg/100 g (pulp samples from the NSuE) to 1.92 ± 1.37 mg/100 g (pulp from the SSuE), and this variation was not significant from one locality to another. The Fe contents reported in the present study were lower than those reported by Akubor (2016) (42 ± 0.6 mg/100 g).

The highest K levels were recorded in pulp from the NSuE (3301.25 ±872.85 mg / 100 g), while the lowest values were recorded in the SSuE (1657.38 ± 338.78 mg / 100 g). There was a significant difference between the K content of the NSuE and the other two zones investigated. However, there was no significant difference between the K levels in the SSE and the NSuE. The values reported in the present study were higher than those reported by Akubor (2016) (764 ± 0.2 mg/100 g).

Mg content varied from 199.13 ± 75.94 mg/100 g (pulp from SSuE) to 257.63 ± 90.15 mg/100 g (pulp from NSuE), and its variation is not significantly different from one locality to another (P-value = 0.088). Mg content reported by Akubor (2016) (113 ± 0.3 mg/100 g) was within the range reported by this study.

The highest Zn levels were recorded in pulp from the NSuE (1.28 ± 0.37 mg/100 g) while the lowest values were recorded in the SSE (0.87 ± 0.21 mg/100 g). There

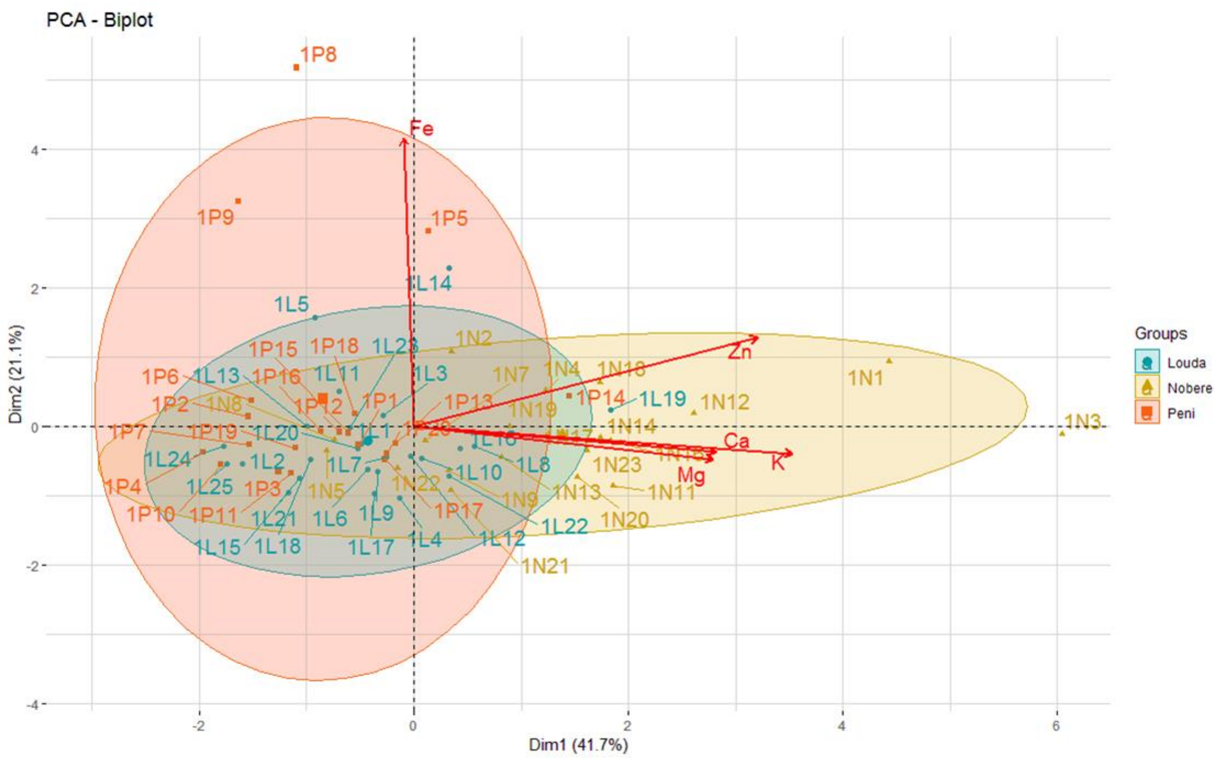

Figure 2. PCA-Biplot of the three selected populations of *Parkia biglobosa (Jacq.) Benth* based on the micronutrients composition of their pulp.

was a significant difference between the Zn levels in the NSuE and the other two zones of the study. On the other hand, there was no significant difference between the Zn levels in the SSuE and the SSE. The Zn content reported by Akubor (2016) (0.8 mg/100 g) was within the range reported by this study.

The highest Ca levels were recorded in the pulp from the NSuE (519.41 ± 458.96 mg/100 g), while the lowest values were recorded in the southern Sahelian ecoregion (240.1 ± 59.23 mg/100 g). There was a significant difference between the Ca content of the NSuE and the SSuE. On the other hand, there was no significant difference between the Ca content of the SSE and the two other zones (NSuE and SSuE). The values of Ca content reported in the present study were higher than those reported by Akubor (2016) (27 ± 0.9 mg/100g).

The variations of mineral contents of *P. biglobosa's* pulp could be explained by the mineral content of the soils as reported by Maranz et al. (2004).

This study showed that the SSE had the highest beta-carotene content (530.52 ± 68.11 µg/100 g), while the SSuE has the lowest (431.86 ± 53.15 µg/100 g). There was a significant difference between the beta-carotene content in the SSE and those in the Sudanian zones. It is also important to note that there was no significant difference between the values of beta-carotene in the Sudanian zones. Beta-carotene content reported in the present study were higher than those reported by Kayalto et al. (2013) (202.69 ± 2.10 µg/100g) and by Olujobi (2012) (11.37 ± 0.26 µg/100 g).

The environment, soil type, fertilizer, water or sunlight intensity can influence significantly the composition of a food (Chadare et al., 2009). That may be partially explained by the variation found in the reported data on the composition of *P. biglobosa's* pulp. Maranz et al. (2004) reported also very high variability in all measured parameters, both within and between populations, during investigation on the chemical composition of 42 populations of the Shea butter (*Vitellaria paradoxa*) from 11 countries.

A PCA was applied to detect any possible clustering of *P. biglobosa* pulp samples based on micronutrient content. The scores of the first two principal components related to the Fe, Zn, Ca, K and Mg content for pulp samples from all 65 *P. biglobosa* trees from the three different localities are presented in Figure 2. The first two principal components explained 62.8% of the total variation, with the first axis explaining 41.7% and the second axis 21.1% of the total variation respectively. The PCA biplot (Figure 2) does not reveal a grouping of values by location but rather a large dispersion of micronutrient values in individuals from the same site. The ellipse formed by the samples from the NSuE samples (Louda) is entirely included in the one formed by

Table 2. Contribution of 100 g of *Parkia biglobosa (Jacq.) Benth* fruit pulp to meet recommended daily intakes of minerals and vitamins.

Nutrient	Target	RDI *	CR (fresh pulp) (%)	CR (dried pulp) (%)
Fe	Women aged 14 to 30	29 mg	1.72-19.81	2-23
K	Adult	2000 mg	47.37-214.16	55-249
Mg	Adult	260 mg	23.26-159.34	27-185
Zn	Lactating women	16.3 mg	2.58-21.53	3-25
Ca	Pregnant woman	800 mg	18.09-325.57	21-378
Beta-carotene	Lactating women	850 µg RE	5.17-12.06	6-14
	Children aged 6 to 36 months	400 µg RE	11.20-24.98	13-29

*FAO/WHO (2001).

the samples from the SSuE (Peni) and the NSuE (Nobere) (Figure 2). This means that most samples in the NSuE (Louda) displayed micronutrients (Fe, Zn, K, Ca, and Mg) similar either to those of the SSuE (Peni) or the North Sahelian ecoregion (Nobere).

Consequently, in each locality, trees with interesting micronutrient characteristics could be found. Table 2 shows the contribution of 100 g of raw edible pulp of *P. biglobosa* to the mineral and vitamin daily recommended intakes. The consumption of 100 g of *P. biglobosa* pulp is able in theory to cover between 18.09 and 325.57% of a pregnant woman's daily Ca needs. It can also cover between 47.37 and 214.16% of the daily K requirements of an adult, between 23.26 and 159.34% of the daily Mg requirements of adults, between 2.58 and 21.53% of the daily Zn requirements of lactating women and between 1.72 and 19.81% of the daily Fe requirements of women aged 14 to 30. Finally, the consumption of 100 g of raw edible pulp would cover between 11.20 to 24.98% of the daily beta-carotene requirements of children aged 6 to 36 months and between 5.17 to 12.06% of the daily beta-carotene requirements of lactating women (FAO/WHO 2001).

Conclusion

This study has comprehensively investigated the physical and chemical composition and nutritional composition of *P. biglobosa* fruit pulp from different ecoregions which are commercially available in West Africa. This is the first detailed report on the nutrient content of pulp as well as on the macronutrients in pulp from the different ecoregion in the same study. The results revealed significant differences in nutrient content between the three localities for macronutrients (ash and lipid) and micronutrients (K, Zn, Ca and beta-carotene). The analyses for the macronutrients as well as the micronutrients did not show a grouping by locality but rather a widely scattered distribution of values for tree individuals from the same tree population. In addition, the study demonstrated that in each ecoregion a broad range of variation in nutrients individuals from the same tree population and that in each locality, superior trees can be found with respect to the content of specific nutrients if compared to the other individuals in the same population. This study underlines the considerable nutritional value of P. biglobosa pulp such as beta-carotene, Mg, K, Ca, Zn and Fe, which can be seen from the potential contribution of 100 g of raw edible pulp to covering recommended daily intakes.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

The research was supported by the Austrian Development Agency within the project on “Nutrition-sensitive forest restoration to enhance the capacity of rural communities in Burkina Faso to adapt to change (2016-2019), led by Bioversity International (Italy). The project was co-financed by the CGIAR research programmes on Forests, Trees and Agriculture (FTA) and Agriculture for Nutrition and Health (A4NH). The researcher appreciated the technicians from Centre National de Semences Forestières (CNSF) for their assistance in the collection of the samples. Finally, Dr Abel Tankoano is thanked for his support in statistical analyses.

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