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Variability of nutrients in *Parkia biglobosa* kernels from three geographical regions in Burkina Faso

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This study aimed to determine the nutritional composition of the kernels of the African locust bean, *Parkia biglobosa*, collected in three populations (Louda, Nobéré and Péni) representative of different environmental conditions, from more arid in the northern population (Louda) to wetter in the most southern population (Péni). Biochemical analyses were carried out using standard methods. Results expressed on a dry basis showed that glutamic acid was the amino acid with highest values in kernels (2.72 - 6.44%). Methionine was the amino acid with lowest values (0.11 - 0.33%). The kernels had an interesting amount of minerals, Fe (4.15 - 18.48 mg), K (662.55 - 2801.69 mg), Mg (178.19 -1624.83 mg), Zn (2.58 - 4.86 mg) and Ca (316.13 - 1731.41 mg). Moisture content varied from 4.49 to 7.56%, carbohydrates from 10.85 to 19.81%, proteins from 30.32 to 43.91%, ashes and lipids respectively from 4.19 to 5.80% and from 21.64 to 30.77%. Samples from Louda contained the highest mean values for proximate composition. Samples from Nobéré contained higher amounts of mineral and amino acids compared to the other two populations. The most important variation between samples of the same location was observed in the mineral composition (CV%> 20% except Zn); Louda was the location with highest dispersion of values. Samples from Péni in the South-Soudanian zone showed overall lower nutritional value. The nutritional composition of *P. biglobosa* kernels varied significantly according to the location where seeds were collected.

Key words: *Parkia biglobosa*, kernels, nutrients, variability, Burkina Faso.

INTRODUCTION

In most of the African countries wild fruit trees constitute an important part of the diet and play an important role in

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income generation. *Parkia biglobosa,* commonly known as African locust bean tree or néré, is one of these species. Like in the case of other plants, for example melon (*Citrullus vulgaris*), castor (*Ricinus* spp.) and soybean (*Glycine max*), its seeds are fermented to produce condiments with high content of proteins (Omafuvbe et al., 2004). 'Soumbala' is the most commonly known natural plant-derived, food condiment used in the savannah regions of West and Central Africa (Adeyeye, 2006). Initially consumed in some West African countries, such as Burkina Faso, Ghana, and Benin, 'Soumbala' became increasingly popular due to its high nutritional value and other medicinal properties, such as the lowering of high blood pressure (Pelig-Ba, 2009). 'Soumbala'is a tasty condiment, a flavor intensifier obtained by traditional alkaline fermentation of *Parkia biglobosa* seeds. The preparation takes place in steps including first boiling, followed by dehulling, a second boiling, fermentation, air drying and molding (Wang and Fung, 1996; Ouoba et al., 2005). The introduction of mechanical dehullers has made the laborious process of dehulling, traditionally done manually, more producer-friendly. With the use of a mechanical device, *P. biglobosa* seeds are dehulled before boiling. 'Soumbala' producers have preferences for raw material coming from specific locations because of the higher quality. The location of the source thus seems to have an influence on the quality and possibly also on the nutritional composition of the seeds (Olujobi, 2012).

Several studies have reported on the high nutritional quality of *P. biglobosa* seeds and kernels with a proximate composition ranging from 21 to 33% for protein, 15 to 22.5% for fat, 3.5 to 5% for ashes and 35 to 49% for carbohydrates (Adeyeye, 2006; Esenwah and Ikenebomeh, 2008; Odebunmi et al., 2010; Elemo et al., 2011; Koura et al., 2014; Nyadanu et al., 2016). Comparing data between studies is not recommended given the different sampling, processing (seeds analyzed with or without hull, boiled or not, etc) and analytical methods applied in different studies. However, comparative studies examining the variation in nutritional composition of *P. biglobosa* kernels from different locations are rare. One of the very few examples is a research conducted by Olujobi (2012).

The objective of this study was to assess the range of variation in nutrient content of the kernels across three different populations (Louda in the South-sahelian zone, Nobéré in the North-Soudanian zone, Péni in the South-soudanian zone) and to assess if differences between tree populations were significant.

MATERIALS AND METHODS

Sampling

The *P. biglobosa* pods were collected from three geographical areas in Burkina Faso, selected across the distribution range of the tree species, along a rainfall gradient: Louda (12°58'54,64''-1°4'56,59'') in the South-Sahelian zone (400-600 mm/year), Nobéré (11°32'31,17''-1°12'35,57'') in the North-Soudanian zone (900-1100 mm/year) and Péni (10°57'22,97''-4°32'21,76'') in the South-Soudanian zone (≥ 1100 mm/year). The three locations have different soil characteristics: Ferruginous soil in Louda (L), eutrophic brown soil in Nobéré (N) and ferralitic soil in Péni (P). Each selected population had to have a minimum of 50 adult trees, all in the reproductive stage, thus able to produce fruits. Twenty to twenty-five healthy trees were randomly identified in each location and mature fruits collected for the characterization. On each tree, a quantity of 6-8 kg of dry pods was collected across the entire crown surface, labeled and bagged in plastic (each marked with site name and tree number) and sent to the laboratory. Sampling took place from April to May 2017.

Sample treatment

The fruit exocarp was separated manually; the pulp was separated from the seeds by pounding the seeds embedded in the pulp using a porcelain mortar. The seeds were washed, drained off, sun-dried for 72 h and dehulled using a mechanical dehuller (prototype CNRST/IRSAT, Ouagadougou, Burkina Faso, 1997) with wheels made of stainless steel. Kernels were powdered and a quantity of 200-300 g was packaged in plastic boxes and conserved at 4°C for analyses.

Biochemical analysis

The amino acids profile was determined with the PICOTAG method using High Performance Liquid Chromatography (Kristofferson, 2011). Minerals (Fe, Zn, Ca, K, Mg) were determined according to AOAC 975.03 (2005) using the Atomic Absorption Spectrophotometric Method (Thermo Scientic AA). Moisture, ash, proteins and fat content were determined according to international standard methods (ISO 20483 2013; ISO 659 2009; ISO 712 2009; ISO 2171 2007); carbohydrate was quantified according to Montreuil and Spik (1969).

Statistical analysis

All analyses were conducted in triplicate. Data were processed to derive descriptive statistic values (e.g., means, coefficient of variation and relative standard deviation). In addition, an analysis of variance (ANOVA) followed by Tukey test was carried out to determine statistical differences between populations with a confidence interval of 95%, using the XLSTAT software, version 2015.4.01. 22368. Finally, to visualise the spread of values for all tree sampled with regard to macronutrients as well as mineral content and essential amino acids, a Principal Component Analyses (PCA) was performed using the FactoMinR package with the RStudio software, version 1.1.463.

RESULTS

The amino acid profiles in *P. biglobosa* kernels from the three populations studied are presented in Table 1. Glutamic acid was found in highest concentrations, varying from 2.72 (for a tree in Louda) to 6.44% (for a tree in Nobéré). Methionine and cysteine were observed in low concentrations, respectively from 0.11 (for a tree in Louda and Péni) to 0.33% (for a tree in Louda and

Table 1. Amino acids profile of *Parkia biglobosa* kernels (g/100 g DM).

Site	Variable	asp	Glu	ser	gly	his	arg	thr	ala	pro	tyr	val	met	cys	ile	leu	phe	lys
Louda (n= 25)[a]	Minimum	1.17	2.72	0.73	0.69	0.43	0.91	0.39	0.73	0.78	0.32	0.53	0.11	0.37	0.43	1.01	0.59	1.23
	Maximum	3.02	6.02	1.64	1.53	0.93	1.91	0.88	1.48	1.70	0.60	1.20	0.33	1.44	0.93	2.35	1.26	3.17
	Mean	2.29*b	4.68**	1.25**	1.21**	0.73**	1.52**	0.66**	1.18**	1.31**	0.48**	0.96**	0.24*	0.83*	0.72**	1.83**	0.96**	2.30**
	CV%	18.66	16.16	15.57	15.27	16.13	15.64	15.17	14.37	15.87	17.49	15.50	18.98	34.64	15.06	16.19	15.33	17.52
Nobéré (n= 20)	Minimum	1.29	4.60	1.27	1.25	0.72	1.44	0.73	1.28	1.28	0.49	1.04	0.17	0.50	0.78	1.97	1.05	2.05
	Maximum	3.36	6.44	1.63	1.54	0.95	2.07	0.95	1.55	1.99	0.84	1.35	0.33	1.26	1.03	2.42	1.40	2.72
	Mean	2.43*	5.57*	1.43*	1.38*	0.83*	1.74*	0.84*	1.41*	1.60*	0.63*	1.19*	0.25*	0.76*	0.90*	2.22*	1.23*	2.47*
	CV%	26.29	9.54	7.50	6.89	9.05	9.70	6.47	6.48	10.28	15.07	7.97	15.41	26.50	8.25	6.85	8.24	8.17
Péni (n= 20)	Minimum	1.50	3.11	0.98	0.80	0.49	1.13	0.48	0.98	0.90	0.38	0.70	0.11	0.21	0.54	1.34	0.81	1.41
	Maximum	2.64	5.50	1.48	1.30	0.77	1.76	0.73	1.54	1.48	0.61	1.10	0.23	0.83	0.85	2.09	1.18	2.20
	Mean	1.99**	4.18***	1.19**	1.00***	0.62***	1.39***	0.59***	1.22**	1.12**	0.49**	0.89***	0.20**	0.55**	0.68**	1.67***	0.97**	1.81***
	CV%	14.06	15.62	12.29	14.70	11.68	13.16	12.70	12.56	15.73	13.44	12.84	15.63	28.52	12.54	13.86	11.73	12.71
All locations (n= 65)	Minimum	1.17	2.72	0.73	0.69	0.43	0.91	0.39	0.73	0.78	0.32	0.53	0.11	0.21	0.43	1.01	0.59	1.23
	Maximum	3.36	6.44	1.64	1.54	0.95	2.07	0.95	1.55	1.99	0.84	1.35	0.33	1.44	1.03	2.42	1.40	3.17
	Mean	2.24	4.80	1.29	1.20	0.73	1.55	0.69	1.26	1.34	0.53	1.01	0.23	0.72	0.76	1.90	1.05	2.20
	SD	0.62	0.89	0.20	0.22	0.13	0.26	0.14	0.19	0.28	0.12	0.19	0.05	0.26	0.14	0.34	0.18	0.43
	P-value	0.00	<10-3	<10-3	<10-3	<10-3	<10-3	<10-3	<10-3	<10-3	<10-3	<10-3	0.00	<10-3	<10-3	<10-3	<10-3	<10-3

[a]Number of trees sampled in each population. [b] values with different number of superscript stars in the same column are significantly different (P-value ≤0.05).

Nobéré) and from 0.21 (for a tree in Péni) to 1.44% (for a tree in Louda). The contents in valine and phenylalanine were equal in various samples from Nobéré and Louda.

The PCA analysis on the content of essential amino acids in *P. biglobosa* kernels, resulted in two main axes explaining 94% of the total variation; 85% was associated with axis 1 and 9% with axis 2. The PCA biplot (Figure 1) displays the variation among the three populations. Samples from Nobéré presented the highest average amounts in amino acids, while samples from Péni showed the lowest average. A significant difference was observed between the two locations for all amino acids. Péni presented the lowest and Louda the highest statistically significant dispersion around the mean amino acid values.

The values of the mineral composition of *P. biglobosa* kernels are presented in Table 2. They are expressed in mg/100 g of dry matter of kernels. The iron (Fe) content of the samples varied from 4.15 mg/100 g (for a tree in Louda) to 18.48 mg/100 g (for a tree in Nobéré); potassium (K) content from 662.55 mg/100 g (for a tree in Péni) to 2801.69 mg/100 g (for a tree in Louda); magnesium (Mg) content from 178.19 mg/100 g (for a tree in Péni) to 1624.83 mg/100 g (for a tree in Nobéré); zinc (Zn) content varied from 2.58 mg/100 g (for a tree in Louda and Péni) to 4.86 mg/100 g (for a tree in Nobéré) and calcium (Ca) from 316.13 mg/100 g (for a tree in Péni) to 1731.41 mg/100 g (for a tree in Louda). By comparing values among the three locations, significant differences were observed for potassium and calcium (P-value < 0.0001). For iron there was no significant difference among the three locations (P-value $= 0.38$). For magnesium and zinc no differences were found between Louda and Péni.

The PCA analysis for minerals (Fe, K, Mg, Zn, Ca) of *P. biglobosa* kernels (Figure 2) shows how the individual trees in each site were plotted against the two main axes, which explained 86% of the total variation, with 58.2% attributed to axis

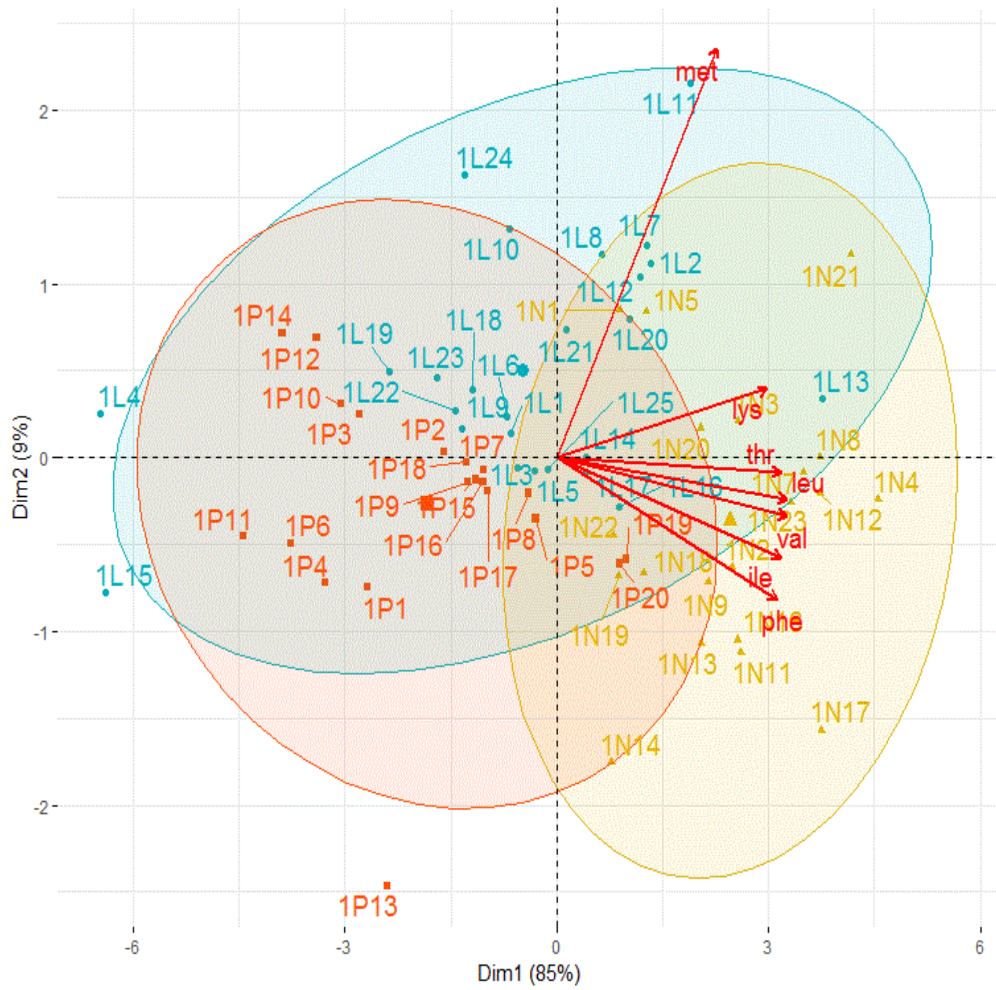

Figure 1. PCA biplot of the essential amino acids of *Parkia biglobosa* kernels. The different circles represent the three populations studied. Vectors show the relative weight of the variables examined (met, lys, thr, leu, ile, val, phe), which determines the spread of points (individual trees) on the biplot. The code associated to each point is the unique identifier of each individual tree.

1 and 27.8% to axis 2. Trees from Péni showed the lowest mineral content and samples from Nobéré the highest mean values; the highest dispersion around the mean in the value of different minerals was observed in Louda.

Mean values of proximate composition of *P. biglobosa* kernels across the three locations were obtained on a dry matter basis (Table 3). Over all samples, moisture varied from 4.49 to 7.56%; the tree with highest moisture content was observed in Louda and the one with lowest moisture content in Nobéré. The kernel samples had a content of carbohydrate, ashes and lipids varying from 10.85 to 19.81, from 4.18 to 5.85% and from 21.28 to 30.94% respectively, with the highest contents observed in Louda and the lowest in Péni; the sample with highest protein content was observed in Nobéré (43.91%) and the sample with lowest protein content in Péni (30.32%). Comparing the three locations, Péni had the highest average moisture (6.78%) and fat (25.83%) content. Louda presented the highest average protein (39.60%), ashes (5.02%) and carbohydrate (17.13%) content. The comparison among sites revealed statistical differences ($P<0.05$) for all nutrients except lipids (P-value of 0.25). More precisely, differences were significant for moisture, carbohydrates and ashes (P-value $<$ 0.0001) and for proteins (P-value $<$ 0.001). For what concerns the protein content, differences between Péni and Nobéré were not significant statistically. The PCA analysis for the proximate composition of *P. biglobosa* kernels (Figure 3) showed a spread of individual trees along the main axes, which explained 71.9% of the total variation, with 37.5% of variation associated to axis 1 and 34.4% to axis 2. The dispersion along axis 1 was mainly related to protein and lipid content, while the dispersal along axis 2 was mainly linked to variation in humidity, ash and carbohydrates. Louda and Nobéré seemed to be more similar between

Table 2. Mineral composition of *Parkia biglobosa* kernels (mg/100 g DM).

Site	Variable	Fe	K	Mg	Zn	Ca
Louda (n= 25)[c]	Minimum	4.15	906.77	186.40	2.58	449.64
	Maximum	13.78	2801.69	1619.45	4.85	1731.41
	Mean	7.83*[d]	1458.69**	475.14**	3.54**	820.88**
	CV%	29.08	43.27	91.38	16.07	36.52
Nobéré (n= 20)	Minimum	4.51	961.66	209.80	3.16	466.52
	Maximum	18.48	2725.31	1624.83	4.86	1571.41
	Mean	7.35*	1921.58*	996.09*	3.76*	1112.21*
	CV%	40.68	36.87	55.92	13.34	32.58
Péni (n= 20)	Minimum	4.87	662.55	178.19	2.58	316.13
	Maximum	13.30	2531.67	1472.11	4.69	1052.59
	Mean	7.31*	1171.46***	488.74**	3.41**	586.05***
	CV%	27.66	41.62	69.31	14.59	34.85
All locations (n= 65)	Minimum	4.15	662.55	178.19	2.58	316.13
	Maximum	18.48	2801.69	1624.83	4.86	1731.41
	Mean	7.52	1512.74	634.05	3.57	838.26
	SD	2.40	682.69	499.07	0.53	357.43
	P-value	0.38	<10-3	<10-3	<10-2	<10-3

[C]Number of trees sampled in each population. [d]values with different number of superscript stars in the same column are significantly different (P-value ≤0.05).

themselves for most of the nutrients assessed, as revealed by both the ANOVA and PCA.

DISCUSSION

The concentrations of methionine and cysteine were higher than those found by Elemo et al. (2011) in dehulled and defatted seeds of *Parkia biglobosa* (cys: 0.1%; met: 0.06%). Glutamic acid and methionine were the amino acids found in highest and lowest concentrations, respectively, among all *P. biglobosa* samples. The same observations were made by Hassan and Umar (2005) in a study on African locust bean. Methionine and cysteine, sulfur containing amino acids, found in low concentrations in our samples, have been reported to be limited in legumes (Baudoin and Maquet 1999; Laurena et al., 1991). Cysteine is an important amino acid due to its positive effect on mineral absorption, particularly zinc (Mendoza, 2002; Sandstrom et al., 1989). Cysteine as well as arginine is functional amino acids. They play an important role in the regulation of various metabolic pathways (Guelzim, 2011).

The study reported a higher minerals content of *P. biglobosa* than that reported by Elemo et al. (2011): iron 9.3 mg/100 g, potassium 1101.5 mg/100 g magnesium and zinc 280.2 mg/100 g and 3.8 mg/100 g respectively, calcium 222.2 mg/100 g.

The high average moisture content in the samples from Péni (6.78%) can be explained by the higher rainfall levels that characterize this site located in the most southern of the three locations investigated, in the South-Soudanian zone. The moisture and carbohydrate content of the present study were lower than those reported in previous studies (Koura et al., 2014; Elemo et al., 2011; Odebunmi et al., 2010; 8.6 to 11.21% for moisture and 41.10 to 48.5 for carbohydrates. The same authors showed amounts of proteins varying from 21.38 to 33.70%, of ashes varying from 3.51 to 5.01 and of fats varying from 15.48 to 22.56%. Our results contain higher values than those previously reported by these authors.

Results show that *P. biglobosa* kernels have a good nutrient content that can be improved during transformation in 'soumbala'. *P. biglobosa* kernels are not consumed raw. The technological process by which they are transformed through fermentation allows an improvement of their nutritional quality, particularly the availability of proteins. The differences in nutrient composition of samples collected from different locations can be attributed to environmental factors, such as soil composition and weather variability, to genetic variability (Koura et al., 2014; Elemo et al., 2011; Odebunmi et al., 2010), or to a combination of these sets of factors. A previous study on *P. biglobosa* (Olujobi, 2012) showed that the location significantly affects the nutritional composition of this species, similarly to our study. The higher values for most nutrients found in our study versus previous studies (Koura et al., 2014; Elemo et al., 2011;

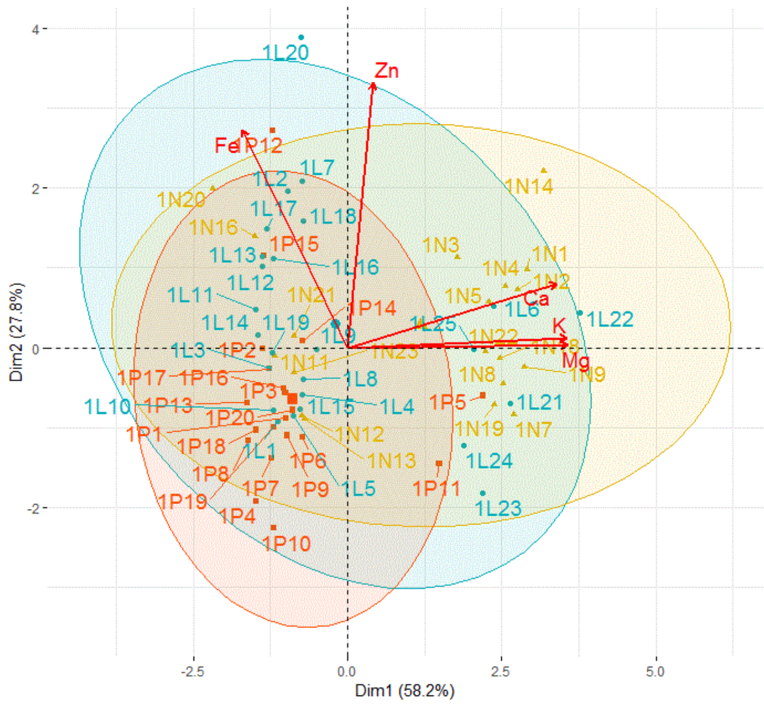

Figure 2. PCA biplot of the mineral composition of *P. biglobosa* kernels. The different circles represent the three populations studied. Vectors show the relative weight of the variables examined (Fe, Zn, Ca, K, Mg), which determines the spread of points (individual trees) on the biplot. The code associated to each point is the unique identifier of each individual tree.

Table 3. Proximate composition of *P. biglobosa* kernels.

Site	Variable	Humidity (%)	Carbohydrates (g/100 g DM)	Proteins (g/100 g DM)	Ashes (g/100 g DM)	Lipids (g/100 g DM)
Louda (n= 25)[e]	Minimum	4.56	13.09	34.60	4.45	21.85
	Maximum	7.56	19.81	43.02	5.80	30.77
	Mean	5.92**[f]	17.13*	39.60*	5.02*	25.23*
	CV%	11.10	10.10	5.78	7.09	8.03
Nobéré (n= 20)	Minimum	4.49	14.35	32.69	4.42	21.64
	Maximum	5.84	18.28	43.91	5.36	30.03
	Mean	5.16***	16.01**	37.99**	4.79**	25.67*
	CV%	7.94	7.28	7.72	5.43	9.69
Péni (n= 20)	Minimum	6.35	10.85	30.32	4.19	21.68
	Maximum	7.27	18.52	42.75	5.15	30.01
	Mean	6.78*	14.97***	38.13**	4.55***	25.83*
	CV%	4.39	13.32	7.73	5.78	8.19
All locations (n= 65)	Minimum	4.49	10.85	30.32	4.19	21.64
	Maximum	7.56	19.81	43.91	5.80	30.03
	Mean	5.95	16.12	38.65	4.80	25.55
	SD	0.82	1.90	2.78	0.36	2.18
	P-value	<10-3	<10-3	<10-2	<10-3	0.25

[e]Number of trees sampled in each population. [f]values with different number of superscript stars in the same column are significantly different (P-value ≤0.05).

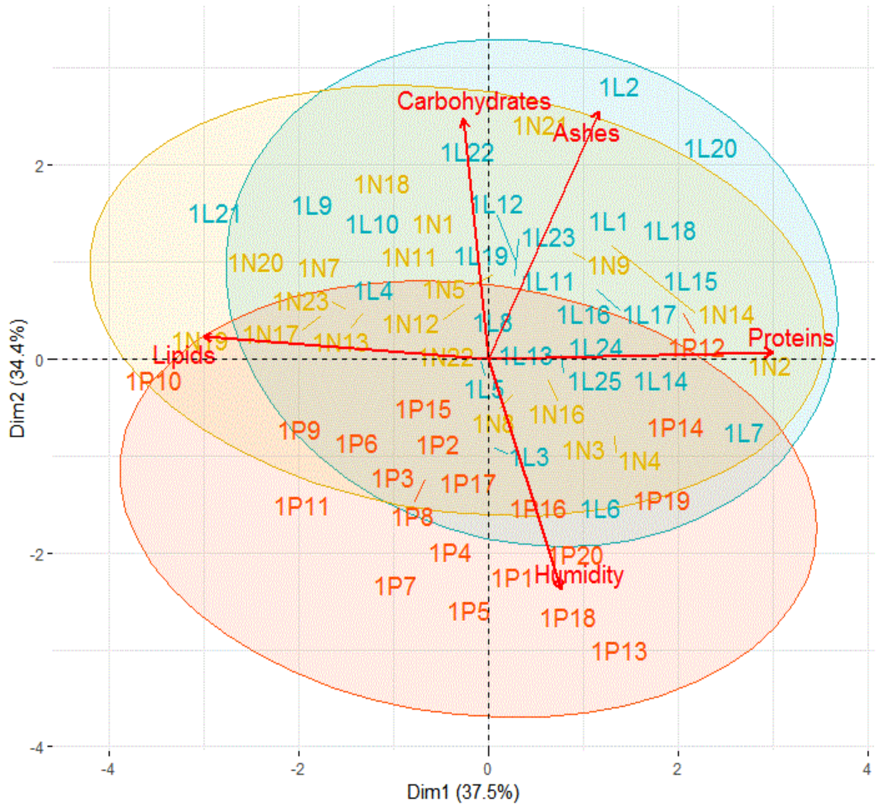

Figure 3. PCA biplot of the proximate composition of *Parkia biglobosa* kernels.
The different circles represent the three populations studied. Vectors show the relative weight of the variables examined (moisture, ashes, lipids, proteins and carbohydrates), which determines the spread of points (tree individuals) on the biplot. The code associated to each point is the unique identifier of each individual tree.

Odebunmi et al., 2010) could be partly explained also by differences in experimental procedures used. For example, in these previous studies, the samples were dried at room temperature and dehulling was not done using mechanic methods (Koura et al., 2014).

Conclusion

The chemical composition of *P. biglobosa* kernels showed that they are a good source of macro- and micronutrients. They contain a fair amount of some amino acids that are known to be limited in legumes and they also contain high amounts of minerals. The nutritional composition of *P. biglobosa* kernels varied significantly according to the location where seeds were collected. Samples from Péni in the South-Soudanian zone showed overall lower nutritional value, while samples from Nobéré and Louda showed more variation. Additional studies would be required to increase understanding of the impact of environmental variables, mainly soil characteristics and genetic factors, on the nutritional composition of *P. biglobosa* kernels.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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