A Physical characteristics of *néré* pods and seeds: influence of location and processors preference.

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Titre courant: Predicting preferences for néré seeds by *soumbala* producers

Abstract

This study aimed to assess the characteristics for *Parkia biglobosa* (Jacq.) R. Br G. Don, seeds to generate data for equipment designing and to understand how producers' preferences are related to the origin and attributes of pods and seeds. The seeds were extracted from mature fruits collected in two successive years from the same trees in three sites located in different ecoregions in Burkina Faso. Length and section circumference of pod were determined according to the description of Dadzie and Orchard (1997), seeds weight according to ISO 520 (2010) description, seeds length, width and thickness according to the description of Aydin (2007). The seeds preferences were determinate by a trained panel composed of 8 processors. A variability was observed in the physical characteristics of pods and seeds depending on the year of collection the origin and the individual tree; however, the larger pods contained the largest seeds. The physical characteristics of the seeds, particularly the weight of 1000 seeds, reflected closely the preferences expressed by *soumbala* producers rather than the origin nor the form. In order to handle more homogeneous seeds batch, dehullers designers could combine sifters to the model with three types of wheels which holes and spacing are 7.32 mm and 4.07 mm for small seeds; 8.28 mm and 4.67 mm for medium seeds and 9.29 mm and 5.39 mm for large respectively.

Keywords: *Parkia biglobosa*, Seed physical characteristics, Processing aptitude, Correlation

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Caractéristiques physiques des gousses et des graines de néré : influence de la localisation et de la préférence des transformateurs.

Résumé

Cette étude visait à évaluer les caractéristiques des graines de *Parkia biglobosa* (Jacq.) R. Br. G. Don, afin de générer des données pour la conception d'équipements et de comprendre comment les préférences des productrices de *Soumbala* sont liées à l'origine et aux attributs des gousses et des graines. Les graines ont été extraites de fruits matures collectés au cours de deux années successives sur les mêmes arbres dans trois sites situés dans différentes écorégions du Burkina Faso. La longueur et le tour de section des gousses ont été déterminés par la méthode décrite par Dadzié et Orchard (1997), le poids de 1000 graines par la méthode ISO 520 (2010), la longueur, la largeur et l'épaisseur des graines par la méthode décrite par Aydin (2007). Les préférences des graines ont été déterminées par un panel formé de 8 transformatrices. Une variabilité a été observée pour les caractéristiques physiques des gousses et des graines en fonction de l'année de collecte, de l'origine et de l'arbre individuel ; cependant, les plus grosses gousses contenaient les plus grosses graines. Les caractéristiques physiques des graines, notamment le poids de 1000 graines, reflétaient étroitement les préférences exprimées par les productrices de *soumbala* plutôt que l'origine ou la forme. Afin de traiter des lots de graines plus homogènes, les concepteurs de décortiqueuses pourraient combiner des tamis au modèle, avec trois types de grilles dont les trous et l'espacement sont respectivement de 7,32 mm et 4,07 mm pour les petites graines ; 8,28 mm et 4,67 mm pour les graines moyennes et 9,29 mm et 5,39 mm pour les grosses graines.

Mots-clés : *Parkia biglobosa*, Caractéristiques physiques des graines, aptitude à la transformation, corrélation.

Introduction

Parkia biglobosa (Jacq.) R. Br. G. Don, is a woody species that is widespread in West Africa and provides multiple goods and services to local populations, hence it has been classified as a "useful" tree (Sina, 2006; Touré, 2018). In West Africa, it is ranks third in importance after baobab and shea trees and is among the 10 most important plant species providing food resources for humans and their livestock in Burkina Faso (Devineau, 2000; Nana & Ouédraogo, 2010).

Several parts of the plant are used as food for humans: flowers are sucked, the whole young pod is roasted and eaten by children, fruits and pulp are consumed as supplementary or subsistence food during the lean season (Thiombiano *et al.*, 2014). Seeds are roasted and used as coffee substitute, or macerated for beverage production or finally fermented, to produce a very popular condiment in West Africa, a flavor enhancer commonly known as *soumbala* in Burkina Faso or *Netetou* or *Dawadawa* respectively in Senegal and Nigeria (Arbonnier, 2002; Matig *et al.*, 2002; Ouoba *et al*., 2003).

Previous study shows that providing optimal conditions for *P. biglobosa* individuals to thrive will lead to better seed quality, required for high-quality *soumbala* (Krongborg *et* *al*., 2014). *Soumbala* producers seem to follow defined criteria when they source seed and have clear preferences for specific locations. Consequently, it is expected that a variability in the physical characteristics of *P. biglobosa* seeds depending on location can be detected and the critical factors that determine seed quality can be identified.

Several studies have been carried out on how *soumbala* is processed, the microorganisms involved in fermentation and the nutritional, hygienic and sensory characteristics of the final edible product (Ndir *et al.*, 2000; Azokpota *et al.*, 2006; Parkouda *et al*., 2009; Somda *et al.*, 2014). Other studies focused on nutritional characteristics of *P. biglobosa* seeds and kernels (Olujobi, 2012; Nyadanou *et al.*, 2016; Guissou *et al.*, 2020).

Due to the harshness of the dehulling process and the need for high quality, nutritious and safe food products, produced in large quantities at low cost, requires efficient processing equipment, designed and operated on the basis of physical properties. Attempts have been made to mechanize the process. However, the efficiency of mechanical dehulling is low probably linked to the lack of knowledge on the physical characteristics of the seeds (Sawaodogo/Lingani *et al.*, 2003; Ahouansou *et al.*, 2017; Coulibaly/Diakité *et al.*, 2020). Few data exist on physical characteristics of seeds and their variation among different locations (Koura *et al.*, 2014). Taking into account the *Parkia* seeds characteristics and the variation of the seed's characteristics will help to release appropriate equipment for the seeds processing, specially the dehulling process. The need for efficient processing equipment that is compatible with the characteristics of processors remains a crucial issue in Africa. No study so far has examined closely the relationship between seeds characteristics and how they affect preferences of *soumbala* producers.

The objective of the present study is to determine the physical characteristics of *P. biglobosa* seeds collected from different locations in order to predict producers' preferences based on pods and seeds attributes and to provide data to improve the efficiency of mechanical dehulling.

1. Material and methods

1.1 Sample collection and preparation

Dried mature *P. biglobosa* pods were collected during two successive years (2017 and 2018) from three different agro-ecological locations in Burkina Faso (Figure 1) according to the description of Guissou *et al.*, (2020).Twenty to twenty-five healthy trees were randomly identified in each location and, from each tree, between 300 and 500 dried mature pods (Figure 2) were collected from across the entire external part of crown, labeled and bagged in plastic (each marked with site name and tree number) and sent to the laboratory. The exocarp of the pods was removed manually. The pulp was separated from the seeds by pounding and seeds were washed, sun dried during 72h.

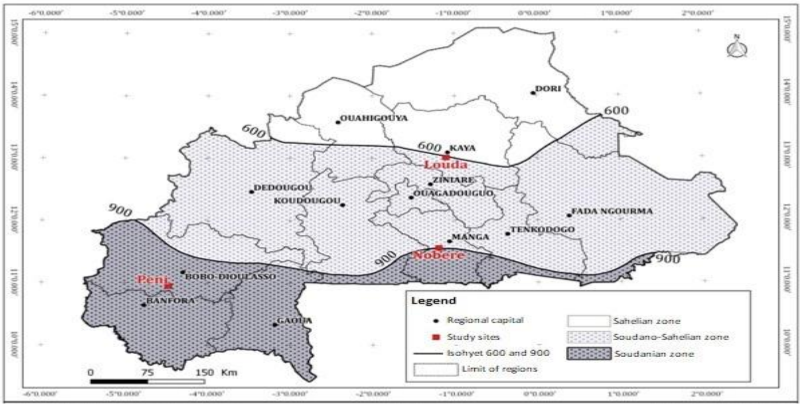

Figure 1 : A map of Burkina Faso showing the location of the three populations sampled (Study sites in red)

Figure 2 : Mature pods of Parkia biglobosa

1.2 Physical analysis

Length and section circumference of 10 pods per sampled tree were measured (Dadzie & Orchard, 1997).

The weight of 1000 seeds was determined according to the method described by the Standard ISO 520 (2010). A quantity of the sample (seeds) was taken and weighted (*We*); then the whole seeds were separated and counted (*N*) and the rest weighted (*Wr*). The weight of 1000 grains (*SWe*) is obtained according the following formula where *% H* is the water content of seeds:

$$SWe = [1000 \times (We - Wr)/N] \times [100/(100 - \%H)]$$

The analysis was performed in triplicate.

The sphericity index of the seeds is an indicator of their shape. The sphericity index (SI) was calculated on the basis of the three dimensions determined from 30 seeds taken at random for each sample batch, using a caliper, according to the description of Aydin (2007): length (L), width (W), thickness (T).

$$SI = (LWT)^{1/3}/L$$

1.3 Sensory analysis

Sensory analysis consisted in a visual assessment of seed shape, in determining seed weight by grasping and holding the seed by hand, in assessing hardness by biting the seed and in a visual assessment of the color of cotyledons. The approach carried out systematically mimic the evaluation carried out by *soumbala* producers when they buy *P. biglobosa* seeds. A trained panel of 8 women was selected, each with more than 20 years of experience in processing *soumbala*.

Approximately 500g of each sample (Figure 3) were placed in a container and labelled.

Figure 3 : Samples of Parkia biglobosa seeds

The samples were presented on a table according to the location and submitted to the appreciation of each member of the panel individually (Watts *et al.*, 1991).

At the end of the assessment, the panel was asked to provide a ranking value of seed quality for each site.

1.4 Statistical analysis

Data were processed to derive descriptive statistic values (e.g., means, coefficient of variation and relative standard deviation). 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. A correlation test between the physical characteristics of pods and those of seeds was carried out.

For sensory preference of seeds, the software R version 3.5.1 was used. The study of the variability of sensory characteristics according to location was performed using the chi2 test at a 95% confidence level. Hierarchical Classification Analysis was carried out in order to make a homogeneity test to verify that the statistical properties of any one part of our dataset were the same across the three locations and between the two years of sampling.

A model was developed to predict a likelihood of seed scoring as “good” or “bad” by *soumbala* producers based on seed characteristics. For this, an ordered probit model was used to identify the characteristic determining seed preferences by producers. The model had the following features:

- dependent variable: the probability of women rating the seed as “good” or “bad” (poor or average);

- explanatory variables: physical traits of seeds, such as width, length, thickness in mm and sphericity index (0-10) and weight in centigrams.

2. Results and discussion

2.1 Physical characteristics of pods and seeds

The physical characteristics of pods and seeds of *P. biglobosa* varied across individual samples (see Table 1).

Table 1: Physical characteristics of pods and seeds of *Parkia biglobosa*

Location	Years		PL	PSt	SL	SW	ST	SSI	Swe
Louda	1	Means	21.30[a]	4.33[ab]	9.37[ab]	7.61[a]	4.79[ab]	0,75[a]	187,76[ab]

		SD	2.81	0.42	0.60	0.54	0.51	0,03	33,16
		CV%	13.20	9.66	6.44	7.10	10.66	3,46	17,66
	2	Means	22.82^{a}	4.35^{ab}	9.16^{ab}	7.34^{ab}	4.55^{ab}	$0,73^{a}$	$182,54^{ab}$
		SD	2.28	0.38	0.47	0.46	0.69	0,03	35,13
		CV%	10.04	8.64	5.10	6.17	14.83	3,85	19,11
Nobéré	1	Means	21.06^{a}	4.42^{ab}	9.06^{ab}	7.31^{ab}	4.46^{ab}	$0,74^{a}$	$166,23^{b}$
		SD	3.13	0.41	0.66	0.44	0.37	0,04	23,70
		CV%	14.87	9.26	7.30	5.96	8.27	5,25	14,26
	2	Means	22.52^{a}	4.22^{b}	8.87^{b}	7.23^{ab}	4.41^{c}	$0,74^{a}$	$170,03^{b}$
		SD	2.62	0.44	0.68	0.54	0.34	0,04	25,88
		CV%	11.62	10.43	7.66	7.49	7.73	5,30	15,22
Péni	1	Means	21.47^{a}	4.58^{a}	9.52^{a}	7.64^{a}	4.93^{a}	$0,75^{a}$	$197,06^{a}$
		SD	2.50	0.43	0.80	0.65	0.46	0,04	30,44
		CV%	11.63	9.34	8.44	8.44	9.40	5,50	15,45
	2	Means	22.60^{a}	4.56^{ab}	9.11^{ab}	7.10^{b}	4.73^{abc}	$0,74^{a}$	$188,21^{ab}$
		SD	2.30	0.35	0.57	0.65	0.40	0,04	33,02
		CV%	10.28	7.62	6.22	9.20	8.51	5,04	17,54
P-value			0,170	0,032	0.020	0.010	0.001	0.871	0.010

Values with different superscript letters in the same column are significantly different (P-value ≤ 0.05);

PL (cm) = pod length; PSt (cm) = pod section circumference; SL (mm) = seed length; SW (mm) = seed width; ST (mm) = seed thickness; SSi= seed sphericity index; SWe (g) = 1000 seeds weight; SD = relative standard deviation; CV%= coefficient of variation.

Pod length values ranged within values reported by Ouédraogo (1995), varying between 205.9 mm and 256.3 mm. Seed length, width and thickness values found in this work are relatively lower than those reported by Ouédraogo (1995), varying from 9.32 to 10.31 mm, from 7.75 to 8.47 mm and from 4.11 to 5.36 mm respectively. But they are relatively higher than those found by Koura *et al.* (2014) ranging from 7.51 to 8.90 mm, from 5.96 to 7.13 mm and from 3.29 to 3.88 mm for length, width and thickness. Seed sizes in the present study fall within the size ranges reported by Ahouansou *et al.* (2010), which are 10.12 ± 1.26 mm, 8.30 ± 1.20 mm and 4.94 ± 0.72 mm for length, thickness and width. Sphericity index values are within the index range reported by Ahouansou *et al.* (2010) and Koura *et al.* (2014) which is 0.68 - 0.8. The weight of 1000 seeds is close to that reported by Koura *et al.* (2014), ranges from 175.99 to 216.86 g but lower than the values (231.66 ± 3.58) found by Ahouansou *et al.* (2010).

Comparing all the samples, a statistical difference was observed except for pods length (P = 0.170) and seeds sphericity index (P = 0.871). Regarding samples collected in two different years, no significant difference was found in Louda, while for Péni and Nobéré a significant difference was observed between years for seed width and thickness. At location level, Louda was not statistically different from Nobéré and Péni.

The correlation between the cross-sectional circumference of pod, seed size and 1000 seeds weight (Table 2) indicates that larger fruits have the longest and thickest seeds, and the highest weight of 1000 seeds. The same observation was made by Koura *et al.* (2014), with the longest seeds having the highest average masses (r = 0.88; p = 0.0219).

Table 2: Coefficients of correlation of the physical characteristics of *Parkia biglobosa* pods and seeds

Variables		PL	PSt	SL	SW	ST	SSI	Swe
PL	R	**1**						
	P-value	**0**						
PSt	R	-0.010	**1**					
	P-value	0.916	**0**					
SL	R	0.034	**0.514**	**1**				
	P-value	0.711	**<0.0001**	**0**				
SW	R	0.173	0.076	**0.416**	**1**			
	P-value	0.058	0.405	**<0.0001**	**0**			
ST	R	-0.030	**0.340**	**0.346**	0.114	**1**		
	P-value	0.741	**0.000**	**0.000**	0.214	**0**		
SSI	R	0.034	**-0.239**	**-0.545**	**0.233**	**0.415**	**1**	
	P-value	0.712	**0.008**	**<0.0001**	**0.010**	**<0.0001**	**0**	
Swe	R	0.115	**0.521**	**0.713**	**0.416**	**0.670**	-0.022	**1**
	P-value	0.209	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	0.811	**0**

PL (cm) = pod length; PSt (cm) = pod section circumference; SL (mm) = seed length; SW (mm) = seed width; ST (mm) = seed thickness; SSi= seed sphericity index; SWe (g) = 1000 seeds weight; R= Coefficient of variability; Significant correlation at P-value ≤ 0.05

The *Parkia biglobosa* seeds dehulling requires the design of a grinding wheel presenting holes with precise dimensions to avoid the breakage or the non-dehulling of the seeds. On the basis of the obtained results, the seeds present dimensions of 8.87 ± 0.68 to 9.52 ± 0.80 mm for length, 7.10 ± 0.65 to 7.64 ± 0.65 mm for width and 4.41 ± 0.34 to 4.93 ± 0.46 mm for thickness and indices of sphericity of 0.73 ± 0.03 and 0.75 ± 0.04 indicating then that the holes and spacing of the grinding wheels must be of 7.32 mm and 4.07 mm for small seeds; 8.28 mm and of 4.67 mm for medium seeds and 9.29 mm and of 5.39 mm for large seeds.

2.2 Sensory characteristics of seeds

Table 3 shows the sensory characteristics of *P. biglobosa* seeds. Seeds had a medium weight and were hard, with yellow-white cotyledons. The shape of the seeds of Nobéré and Péni were described as round for the majority. Those of Louda for the 2nd year had a shape other than round (64% of the samples). Indeed, for the second year of collection, more than 70% of the samples from this location had a sphericity index below the average (0.74). According to Ouédraogo (1995), seeds of *P. biglobosa* in addition to the rounded shape can be longer than larger (oblong form), egg-shaped or larger towards the end (oval and obovate respectively) or flattened and elliptical. All characteristics were acceptable to the panel for more than half of the samples except for the weight at Nobéré (44%).

The site Péni was ranked 1st by 50% of the panel for the two successive years, Louda 2nd by 50% and 75% of the panel respectively for the 1st and 2nd year and Nobéré 3rd by 87.5% and 50% of the panel respectively for the 1st and 2nd year.

Table 3: Description and assessment of the physical characteristics of *Parkia biglobosa* seeds by *soumbala* growers

Year	Location	Form		Weight		Hardness		Cotyledon color		Lot Rank
		Description	Appreciation	Description	Appreciation	Description	Appreciation	Description	Appreciation	
1	Louda	Round (76%)	Acceptable (64%)	Medium (56%)	Acceptable (64%)	Hard (52%)	Acceptable (60%)	Yellow-white (96%)	Acceptable (76%)	2nd (50%)
	Nobéré	Round (55%)	Acceptable (70%)	Medium (50%)	Acceptable (65%)	Hard (90%)	Acceptable (55%)	Yellow-white (100%)	Acceptable (50%)	3rd (87.5%)
	Péni	Round (80%)	Acceptable (55%)	Medium (80%)	Acceptable (60%)	Hard (55%)	Acceptable (55%)	Yellow-white (100%)	Acceptable (55%)	1st (50%)
2	Louda	Others (64%)	Acceptable (50%)	Medium (50%)	Acceptable (64.28%)	Hard (71%)	Acceptable (64.29%)	Yellow-white (85.71)	Acceptable (50%)	2nd (75%)
	Nobéré	Round (60%)	Acceptable (72%)	Medium (48%)	Acceptable (44%)	Hard (68%)	Acceptable (64%)	Yellow-white (95.24)	Acceptable (56%)	3rd (50%)
	Péni	Round (63.64%)	Acceptable (72.73%)	Medium (50%)	Acceptable (68.18)	Hard (68.18)	Acceptable (77.27)	Yellow-white (100%)	Acceptable (59%)	1st (50%)

Values in brackets for the description and appreciation (form, weight, hardness and cotyledon color) percentage of sample; Values in brackets for the lot rank= percentage of panel member

Figure 4 shows the grouping of *P. biglobosa* seeds according to physical characteristics after the application of the Hierarchical Classification Analysis

Three clusters (the traits of each presented in table 4) of fairly homogeneous samples emerged from this analysis: C1 characterized by large, elongated and heavy seeds, grouped the majority of samples (19, 18 and 19 for Louda, Nobéré and Péni respectively); C2, consisting mostly of samples from Nobéré (19) and less than half of the other two locations (7 from Louda and 9 from Péni) was characterized by seeds that are below average on all variables; C3 (14 from Péni, 8 from Nobéré and 6 from Louda) was characterized by spherical, large, thick and heavy seeds. The Pearson test revealed no clustering of characteristics according to location (P=0.0083), meaning that the samples from each location did not have homogeneous specific characteristics. Indeed, a study conducted by Bockstaller (1993) on maize revealed that the shape of the grain depended on the space available for its growth. Thus, for the same pod, the seeds at the base and top will be rounder and thicker, whereas those in the middle, compressed by their neighbors, will be flat. Ouédraogo (1995) reports that farmers are aware that there is a difference in the characteristics of the fruits and seeds of *P. biglobosa* and in their ability to produce good *soumbala* between trees in the same stand. However, the location of Péni ranked 1st in the two successive years had the majority of its samples in clusters C1 and C3. Nobéré which ranked 3rd in the two successive years had more than half of its samples (19) included in cluster C2 (presenting the least appreciated characteristics).

In view of the non-homogeneity of the characteristics of seeds and taking into account the fact that seeds of several origins are often mixed during collection and marketing, it would be necessary to design models of dehullers coupled with sifters in order to process them by homogeneous group. Thus, the operating parameters could be adjusted according to the characteristics of each batch. This would lead to a higher shelling rate and a reduction in the breaking rate.

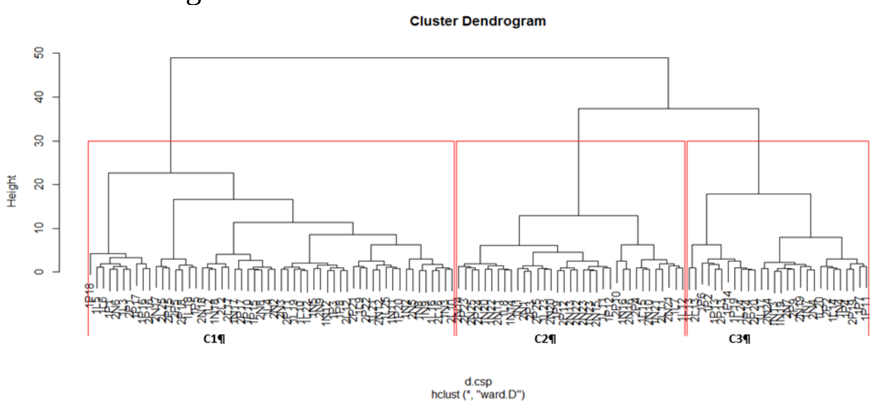

Figure 4: Ascending hierarchical classification of *Parkia biglobosa* seeds according to physical characteristics (The red plots separate 3 clusters of individuals: Cluster1; Cluster2; Cluster3)

Table 4: Characteristics of the observed clusters

Variables	Overall mean	Ratio to the Overall mean		
		C1	C2	C3
Length	9.18	1.0556	0.9377	0.9668
Width	7.37	1.0081	0.9495	1.0470
Thickness	4.65	1.0084	0.9264	1.0752
Spericity index	0.74	0.9687	0.9994	1.0634
1000 seeds weight	182.09	1.0866	0.8283	1.0414

C= Cluster

2.3 Predicting preferences for *Parkia biglobosa* seeds by soumbala producers

Table 5 presents the ordered Probit model of seed preference predictions by *soumbala* producers. It appeared that length, width and sphericity of the seed were negatively correlated with the level of appreciation by *soumbala* producers: the higher their value, the lower the ranking. On the contrary, weight of seed and its thickness were positively correlated with ranking values. However, only seed weight had a significant coefficient at the 5% significance level. By looking at the marginal effects of seed weight on the probability of seeds being qualified as good, it appears that an increase in seed weight by one centigram leads to an increase in the probability of a positive ranking by 12.74%. Finally, the established model indicates good predictive power by correctly classifying 86% of the seeds in their observed grade.

Table 5: Ordered Probit model of the prediction of seed preferences

Variables	Prediction coefficient	P-value	dy/dx for the "good" modality (%)
Seed length	-1.18	0.727	-26.88
Seed width	-0.19	0.931	-43.19
Seed thickness	0.03	0.993	0.58
Sphericity index	-0.13	0.842	-28.55
Weight	0.56	0.000	12.74
Constant	-10.15		

The probability that a seed is good is 0.14; dy/dx>0 is the determining factor at P≤0,05

It could therefore be said that physical characteristics especially seed weight guide preferences for *P. biglobosa* seeds. The higher the weight of seeds, the more preferred they were. Seeds weight is the most discriminating factor compared to other commercial criteria that strongly condition the selection and purchase of seeds by food professionals (Songre-Ouattara *et al.,* 2005). According to producers, high weight would be synonymous with maturity and the heavy seeds would give good *soumbala*.

Conclusion

This study revealed that the physical characteristics of *Parkia biglobosa* seeds varied with year and location. The preferences of *soumbala* producers are determined by the physical characteristics of the seeds and these do not correspond to distinct locations. Despite some minor variations, the perception of physical characteristics by the producers was in line with the results of the laboratory analyses, thus demonstrating their good knowledge and the relevance of their selection criteria. Seed weight could be used as the predictive characteristic of *Parkia biglobosa* seed preferences. Due to the year to year and location to location variation in the physical characteristics, dehullers designers should consider adding sifters to the model in order to handle more homogeneous seeds batch with wheels which characteristics best match those of the seeds.

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