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# Physicochemical Characterisation of *Parkia biglobosa* Benth Seed in View of Improving *Daddawa* Condiment Production in Cameroon

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## ABSTRACT

*Daddawa* is a food condiment produced by fermentation of African locust bean seed (*Parkia biglobosa* Benth). Several difficulties are encountered during the transformation of these seeds into *Daddawa.* To overcome these difficulties, it is important to calibrate the seeds in different classes, to evaluate their physico-chemical properties before cooking at 96°C using the traditional method. The cooked seeds were manually dehulled and the number of dehulled seeds was evaluated. The results showed that the seed mass varies from 0.17-0.55 g, length from 0.90-1.50 cm, width from 0.70-1.10 cm and thickness between 0.30-0.60 cm. Calibre 1 (mass < 0.30 g), calibre 2 (0.30 g ≤ mass ≤ 0.40 g) and calibre 3 (mass > 0.40 g) were identified on a mass basis. Cotyledon chemical composition [lipid (20.39-22.9 g/100 g); total carbohydrates (34.24-39.59 g/100 g); total proteins (73.60-77.27 g/100 g) and total ash (5.92-7.09 g/100 g)] increased with the calibre, while the seed coat and number of seeds/kg decreased. The percentage of dehulled seeds was lower with calibre 1 (51.25 ± 1.88%) while whole sample, calibre 2 and 3 were 61.75 ± 2.75, 69.0 ± 3.0 and 70.0 ± 7.0%, respectively. Seeds (calibre 1) with a high percentage of seed coat (33.72 ± 0.64 %) needed a long cooking time (more than 10 hours) than those (calibre 2 and 3) with a low percentage of seed coat (30.66-31.17%) during the softening process. Calibre 2 and 3 had the lowest amount of seed coat and highest percentage of dehulled seed. These calibres could be used to reduce the cooking time of seed during the softening process.

**Keywords:** axial dimension, dehulled seeds, calibration, cooked, physicochemical properties
**Abbreviations: %DS**, percentage of dehulled seeds; **pers**. **obs**, personal observation

## INTRODUCTION

*Daddawa* is a food condiment produced by fermentation of African locust bean seed (*Parkia biglobosa*) (Odunfa 1985, 1986). This condiment is popular and used by several ethnics groups (*dii*, *foulbé*, *haussa*, *laka*, *mafa*, *mboum*, *mundang*, *ngambaye*) in the Northern part of Cameroon. It constitutes an important source of proteins (34-54%) and lipids (19-21%) (Diawara *et al.* 1998; N'dir *et al.* 2000; Koné 2001; Ouoba *et al.* 2003). This traditional highly proteineous condiment, used for flavouring soups and stews, is produced by alkaline fermentation (Dakwa *et al.* 2001). Many difficulties are encountered during the transformation of locust bean seeds into *Daddawa.* The most difficult step is the cooking and dehulling of locust bean seeds using the traditional method. This method hap is laborious and time consuming due to the hard seed coats, which must be dehulled after a long cooking time (24-72 h) (Bricas and Cheyns 1995; Ogunjimi *et al.* 2002). At the maturity, the coat is dry, therefore by rendering the access to the almond difficult, leading to long time cooking. These were the focus of our study.

Dried bean seeds are cooked in water in order to soften the seed cell walls and the starchy granules within them. Cooking the seeds to the point at which the coat splits depends on it composition and the cooking medium (Kristin 2008). It is therefore important to characterize the seeds physically. To overcome the cooking and dehulling difficulties for processing and development of improved methods using suitable techniques, the physicochemicals properties of the seeds need to be mastered.

Our study was carried out to determine some physicals properties of locust bean seeds, with the aim of calibrating the seeds and chemical properties of different calibres to apply to the process of dehulling by cooking using the traditional method.

## MATERIALS AND METHODS

The scheme of the work is shown in **Fig. 1**.

### Seed samples

African locust bean seeds were bought at the local market in Garoua in the Northern region of Cameroon. The seeds separated after eliminating the debris, the damaged seeds and foreign materials before calibrating according to Codex [Codex standard 66 (1981); Codex standard 171 (1995)] and the Commission Canadienne des Graines (2007) (**Fig. 1**).

### Physical properties of seeds

To determine the seed size, 100 seeds were randomly selected following a similar method described by Dutta *et al*. (1988). For each seed, the three principal axial dimensions namely length, width and thickness were measured using an electronic vernier caliper (Digital Caliper; precision 0.10 mm, Mitutoyo France) and the weight was obtained with the help of an electronic balance (precision to 0.001 g, Sartorius LP 620P, AG GÖTTINGEN Germany) (**Fig. 2**). The results were the average of 100 seeds.

### Calibration method

Calibration was performed according to Codex [Codex standard

Received: 22 September, 2010. Accepted: 1 June, 2011.

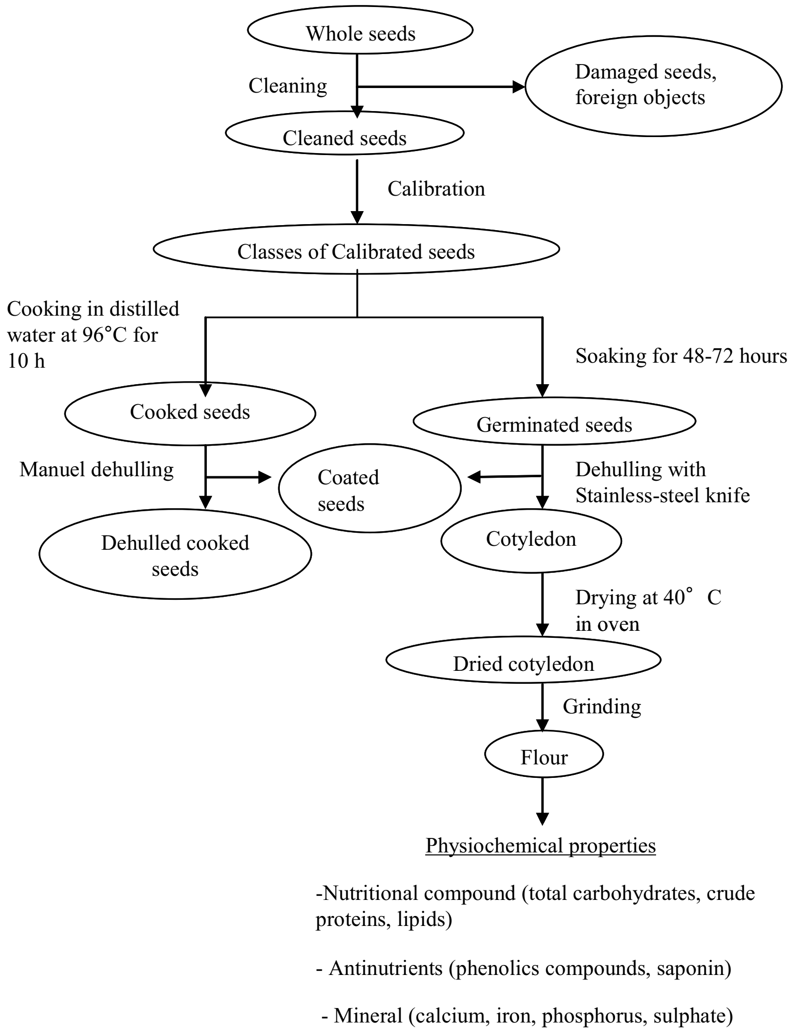


**Fig. 1 Calibration procedure of seeds.**

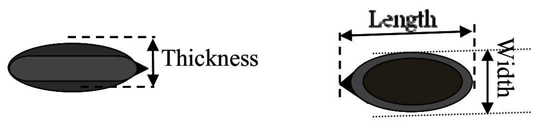


**Fig. 2 Measurement of principal axial dimensions of seeds.**

66 (1981); Codex standard 171 (1995)] and the Commission Canadienne des Graines (2007).

One thousand seeds and cotyledon weight (W1000s) were obtained with the help of an electronic balance. For each seed and cotyledon, the weight was measured. Since it is an important parameter in the softening process, the seeds were classified into three calibres heavy, medium and light, respectively, based on their mass. The ratios of various seed dimensions and their mass were determined and the relationship between them was established.

## Proximate analysis

The moisture content of the seeds was determined using the AOAC method (1990). This consists of the oven drying of seeds samples at 103 ± 2°C.

The seed cotyledons of each calibre were obtained by soaking the seeds for 24 to 72 h until the coat split. After this, the cotyledon was removed with the stainless-steel knife and dried at 40°C for 48 h in an oven and then, ground into flour using mortar and Moulinex (Culatti type MFC CZ13 CE). Proximate composition was determined on cotyledon flour of each calibre. To characterize the cotyledon: dry matter content was obtained according to the AOAC method (1990); total lipids by Bourely (1982); total nitrogen and crude proteins content (N × 6.25) was determined by the Kjeldahl method (Devani *et al.* 1989); total carbohydrates (Dubois *et al.* 1956), total phenolic compounds (Marigo 1973); saponine (Kozol 1990); ash contents (AFNOR 1982).

For mineral composition, seed flour was digested with concentrated chloric acid 35% (Para nalysis PANREAC Barcelona-Madrid, Spain) and mineral constituents were determinate by classic methods: calcium (AFNOR 1982); phosphore and sulphate (Rodier 1978); iron (AFNOR 1986).

## Cooking procedure

1000 g of raw African locust bean of each calibre were boiled for 10 h in distilled water at 96°C and further cooled in distilled water for 10 min. After that, excess water was drained out and the seeds were manually dehulled. At the same time the number of dehulled seed was counted and further removal of the seed coat was achieved by rubbing the cotyledon between the palms of the hand and washing with distilled water.

To determine the percentage of dehulled seeds (% DS), 100 boiled seeds were randomly selected following a similar method described by Dutta *et al.* (1988). For each calibre, the ratio between number of dehulled seeds and boiled seeds were determined and the relationships established as follow: (%DS) = (Number of dehulled seed / Number of boiled seed) × 100.

## Statistical analysis

A completely randomized design was used for analysis of variance of physical characteristics and percentage of dehullind data. The mean values for all parameters were examined for significance by analysis of variance and when significant difference ($P \leq 0.05$) was observed, mean separation was accomplished by Duncan's multiple range test using STATISTICA software (Statsoft. Inc., 1999).

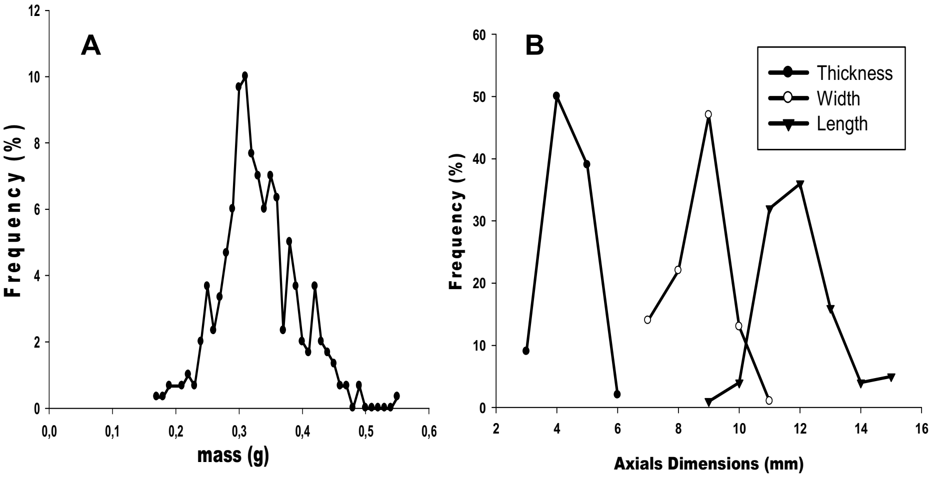


**Fig. 3** Frequencies distribution in percentage of mass (**A**); axial dimension (**B**) of seeds sample.

## RESULTS AND DISCUSSION

### Polygon of frequencies

The size distribution of locust bean seeds presented in **Fig. 3** showed respectively the distribution frequency curves for the weight, length, width and thickness of the seed at a moisture content of 7.33% (db).

From the results, it is observed that the seed mass was found to range from 0.17 to 0.55 g with average of 0.36 ± 0.09 g (**Fig. 3A**). The seed length varied from 0.90 to 1.50 cm with average of 1.15 ± 0.1 cm (**Fig. 3B**), while the width was between 0.70 to 1.10 cm with the average of 0.85 ± 0.10 cm (**Fig. 3B**) and the thickness of between 0.30 to 0.50 cm (average 0.40 ± 0.07 cm) (**Fig. 3B**). These physical characteristics of seeds are higher than those reported by Campbell-Platt (1980) for *Parkia biglobosa* seeds [length (0.90 - 1.50 cm), width (0.80 - 1.10 cm) and mass (0.25 g)] and Ogunjimi *et al.* (2002) obtained for *Parkia fillicoidea* which are: length (1.01 ± 0.07 cm), width (0.72 ± 0.06 cm), thickness (0.55 ± 0.03 cm) and mass (0.28 ± 0.04 g), except for thickness values, which are lesser than the values recorded by Ogunjimi *et al.* (2002). According to these results, axial dimensions varied with species and regions (Pons and Frizman 1996; Ratnayake *et al.* 1999). The relation between mass and axial dimension of each seed showed that it was not significant correlation ($r^2 = 0.43$; 0.31; 0.39; $P \leq 0.05$; for length, width and thickness, respectively) between them. The following general expression of the correlation can be used to describe the relationships between mass and the axial dimensions of the seed.

Length = 7.98 + 10.73 mass ($r^2 = 0.43$, $P \leq 0.05$);

Width = 6.38 + 6.12 mass ($r^2 = 0.31$, $P \leq 0.05$);

Thickness = 2.26 + 5.62 mass ($r^2 = 0.39$, $P \leq 0.05$).

Numerically, the seed length, width and thickness (in cm) was 3.19, 2.36, and 1.11 times its mass in g. This parameter is useful in determining the effective weight which could be used in the theoretical estimation of seed volume in softening process. According to Kristin (2008), softening of seed could vary with axial dimension of each seed.

### Calibration method

The experimental conditions for cooking time of seeds

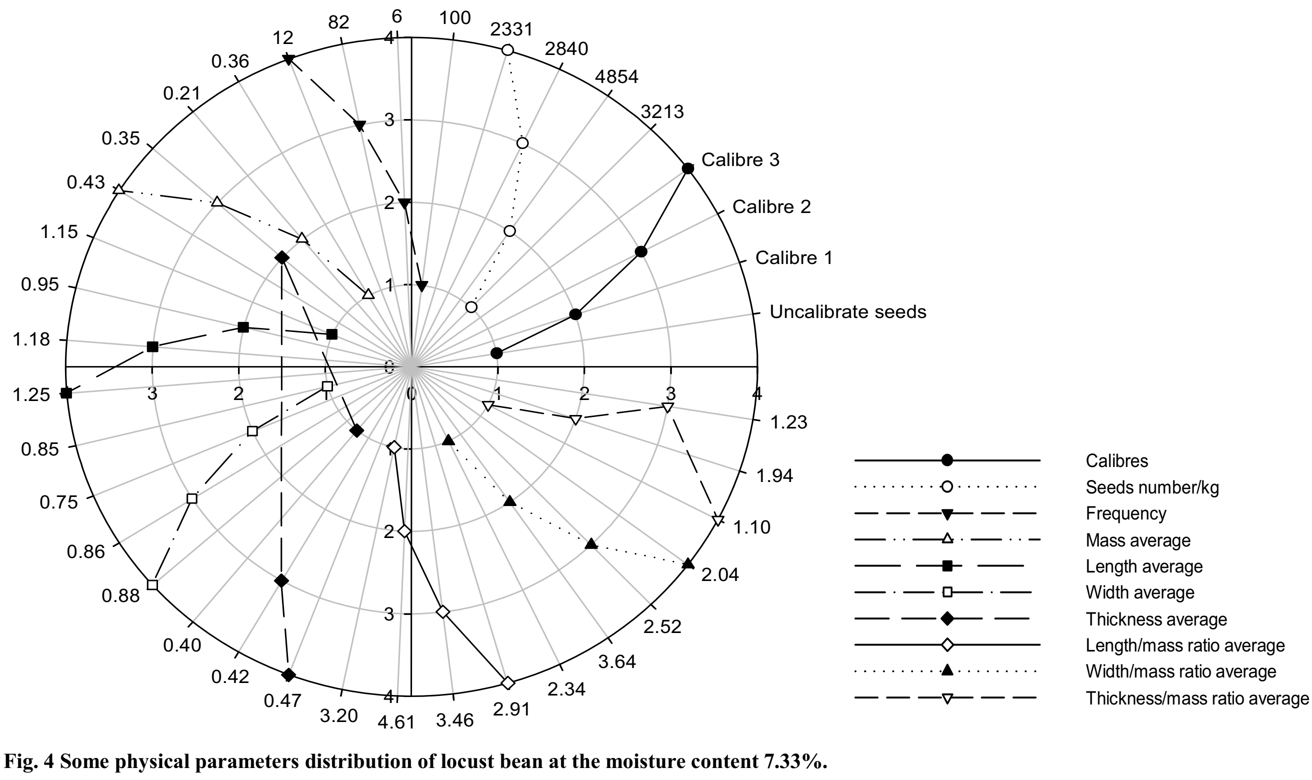


**Fig. 4 Some physical parameters distribution of locust bean at the moisture content 7.33%.**

**Table 1** Physico-chemical properties of cotyledon of African locust bean with respect to calibre.

| | Calibre 1 | Calibre 2 | Calibre 3 |
|---|---|---|---|
| **Whole flours*** | | | |
| Cotyledon/whole seed (g/100 g) | 64.51 ± 0.71 a | 65.22 ± 0.93 a | 66.36 ± 0.67 a |
| Seed coat/whole seed (g/100 g) | 33.72 ± 0.64 a | 31.17 ± 0.12 a | 30.66 ± 1.06 a |
| Number of seed/kg | 4,854 ± 4 b | 2,840 ± 3 a | 2,331 ± 2 a |
| Dry matter (g/100 g) | 92.79 ± 0.01 a | 92.61 ± 0.05 ab | 92.50 ± 0.07 b |
| Total lipids (g/100 g) | 20.39 ± 0.04 a | 22.69 ± 0.12 b | 22.91 ± 0.05 b |
| **Defatted flours*** | | | |
| Total carbohydrates (g/100 g) | 34.24 ± 1.47 a | 39.34 ± 0.18 b | 39.59 ± 0.37 b |
| Crude proteins (g/100 g) | 73.60 ± 0.42 a | 75.74 ± 0.29 b | 77.27 ± 0.45 b |
| Phenolics Compounds (g/100 g) | 0.31 ± 0.01 a | 0.33 ± 0.01 b | 0.37 ± 0.01 b |
| Saponin (mg/100 g) | 0.79 ± 0.06 a | 1.20 ± 0.10 b | 1.31 ± 0.06 b |
| Total ash (g/100 g) | 5.92 ± 0.77 a | 6.84 ± 0.26 b | 7.09 ± 0.02 b |
| Calcium (mg/100 g) | 36.67 ± 0.78 a | 43.78 ± 1.83 b | 54.98 ± 3.79 c |
| Iron (mg/100 g) | 15.62 ± 0.63 a | 40.96 ± 0.25 a | 45.39 ± 1.20 a |
| Phosphorus (mg/100 g) | 354.06 ± 2.65 a | 355.95 ± 0.95 a | 440.86 ± 1.48 b |
| Sulphate (mg/100 g) | 3.85 ± 0.13 a | 3.85 ± 0.28 a | 7.41 ± 0.26 b |

*n* = 3, mean values are shown, SD was always less than 20%).
* Different letters within a line indicate significant differences according to Student's *t*-test ($P < 0.05$).

showed that after 10 hrs of cooking at 96°C, 80% of undehulled seeds presented a weight less than 0.30 g (pers. obs.). Thus, the objective of the calibration was to select some seeds which could present a less time of softening and a maximum percentage of dehulling. The results obtained at moisture 7.33% of dried bean matters are presented in **Fig. 4** for the three calibres compared to the uncalibrated whole seed. The seeds were divided in three calibres according to their weight: light (calibre 1; mass < 0.3 g); Medium (calibre 2; 0.3 g ≤ mass ≤ 0.4 g); heavy (calibre 3, mass > 0.4 g).

Calibre 1 were seeds with the mass below 0.25 g. It constituted 6% of whole sample of seeds. The number of seeds per Kg of seeds was 4,854 ± 4. The mass average was 0.21 ± 0.02 g and the axial dimensions were as follow: length 0.95 ± 0.10 cm; width, 0.75 ± 0.03 cm and the thickness 0.35 ± 0.05 cm.

Calibre 2 were seeds with mass range between 0.25 to 0.40 g. This group represented 82% of the whole sample of seeds. The number of seed per Kg of seeds from this calibre was 2,840 ± 3. The average mass was 0.35 ± 0.03 g, axial dimensions of seed were: length 1.18 ± 0.08 cm; width, 0.86 ± 0.08 cm and the thickness 0.42 ± 0.05 cm. Numerically, this group was 14 times representative than the calibre 1 and 7 times than the calibre 3.

Calibre 3 were seeds with mass over 0.40 g. It represented 12% whole sample of seeds and characterized by 2,331 ± 2 seeds per Kg of seeds; average of mass 0.43 ± 0.01 g; length 1.25 ± 0.01 cm; width, 0.88 ± 0.06 cm and the thickness 0.47 ± 0.04 cm.

In general, the axial parameters of the studied seeds increased with mass. The heavier seeds were broader and larger than the medium and light seeds. There was a significant difference between calibres 1, 2 and 3 when the number of seed per Kg of seeds; the average mass and length of each seed were concerned. While, significant difference between calibre 2 and 3 was not observed with width and thickness. These axial dimensions would not be used like a calibration's parameter in this study. In this case, the use of ratios (axial dimension/mass) could be an important criterion of differentiation. The ratios showed that axial dimension and mass of seeds are significantly correlated ($P \leq 0.01$) (**Fig. 4**). These ratios decreased when the mass of seed increases as well as the length, the width or the thickness was concerned. This would be an important consideration in the selection of seed in view of softening processing. Numerically, the ratios showed that the seed length, width, thickness in cm were 3. 20; 2.33; 1.10 times its mass in gramme. These observations are similar to the findings of Ogunjimi *et al.* (2002) in the seeds of *P. fillicoidea.* He recorded the highest values (3.69) of the ratio with this species. It was reported that, axial dimensions varied with species and regions (Pons and Frizman 1996; Ratnayake *et al.* 1999). The physical characteristics of the seeds are significant indicators of *Daddawa* production, commercial quality, handling and storage.

## Physicochemical properties of different calibres

The proximate composition of different calibres (1, 2 and 3) of the African locust bean seeds are presented in **Table 1**.

The results indicated that the cotyledon constitutes more than 64% of the seed and the seed coat less than 33%. Seeds of calibres 2 and 3 produced large sized cotyledon than the calibre 1. Similar result was noticed on *guna* seed (*Citrullus colocynthis*) (Aviara and Haque 2000) and in *P. fillicoidea* seeds (Ogunjimi *et al.* 2002). The amount of cotyledon increases with the mass of seed, while the seed coat decreases when the mass of seed increases. This could be an advantage in the softening process and could reduce the cooking time (De León *et al.* 1989; Kristin 2008). According to these searchers, the cooking time decreased with the decreasing of the amount of seeds coats and the increasing of the amount of cotyledon, thus the chemical compounds influenced the cooking time.

The chemical analysis of cotyledon of different calibres in general showed that cotyledon contained the highest amount of crude protein (73.60-77.27% of defatted matter), carbohydrates (34.24-39.59% of defatted matter) and total lipid (20.39-22.91%) and varied with the mass of seed. However, the dry matter content of the cotyledon of calibre 3 was significantly higher than that of the calibre 1. But it was not significantly higher than that observed in calibre 2 (**Table 1**). Calibres 2 and 3 had a significantly higher protein; carbohydrates and lipids values than that content in calibre 1 ($P \leq 0.05$). The high content value (92%) of dried matter of cotyledon is similar to that reported (91.4%) by Omafuvbe *et al.* (2004) and Osuntogun *et al.* (2004) in Africa locust beans. These values are higher than that obtain by Alabi *et al.* (2005) which was 39.55% in the same sample.

The total lipids (20.39 - 22.91%) were higher than the results (16 - 18%) obtained by Omafuvbe *et al.* (2004) and Alabi *et al.* (2005), but lower than the values (31 - 40%) reported by Campbell-Platt (1980) and Diawara *et al.* (1998) in the cotyledon of *P. biglobosa* seeds.

The protein content (73.60 - 77.27%**)** of the cotyledon of *P. biglobosa* seeds was higher than those obtained by Okpala (1990), Alabi (1993); Obizoba (1998) and Alabi *et al.* (2005) which are ranged between 31 - 34% (db).

The total carbohydrates found (34.24 - 39.59%) was lower than those obtained (46.36% of db) by Okpala (1990), Alabi (1993) and Alabi *et al*. (2005) in the cotyledon of *P. biglobosa* seeds. This value of total carbohydrates found would facilitate the fermentation process of seeds.

The total crude phenolic compounds contents of both the calibre 1 (0.31 ± 0.01%) and the calibre 2 (0.33 ±

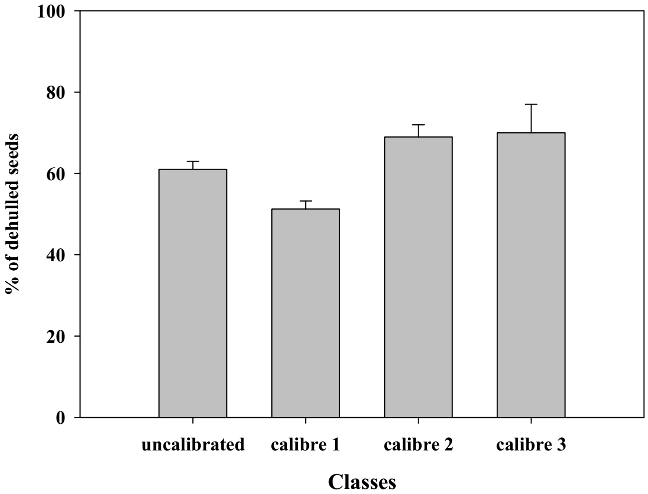


**Fig. 5 Evolution of percentage of dehulled seed with the respect to the mass of seed and calibres after 10 hours of cooking.** Values represent mean ± standard error (SE).

0.01%) were significantly lower than that of the cotyledon of calibre 3 (0.37 ± 0.06%). On the other hand, the saponin of both calibre 2 (1.20 ± 0.10%) and 3 (1.31 ± 0.06%) were significantly higher than those of the cotyledon of calibre 1 (0.80 ± 0.01%). This indicated that oil derived from cotyledon of calibres 2 and 3 could be useful for soap making.

The ash content of raw African locust bean seeds was 5.92 - 7.10%. These results agreed favourably with values (5.92%) reported earlier by Dashak *et al.* (2001) and Omafuvbe *et al.* (2004) but were higher than that (3.95%) obtained by Alabi *et al.* (2005) in *P. biglobosa* seeds in Nigeria.

Mineral contents (**Table 1**), iron (15.623 - 45.390 mg/100 g); phosphorus (354.06 - 440.86 mg/100 g); sulphate (3.85 - 7.41 mg/100 g); calcium (36.67-54.98 mg/100 g) increased with the calibre. According to Walker and Kochhar (1982) legumes are relatively found to be rich in calcium and iron but in *P. biglobosa*, they were found to be lesser than beans, peas and rice (Paul and Southgate 1978).

## Evaluation of percentage of dehulled seed

The objective here was to compare the different calibre and to select seeds with reduced cooking time during the softening process.

**Fig. 5** shows that the mass of seed influenced ($P \leq 0.05$) the percentage of dehulled seed

For the same cooking time (10 hrs) the percentage of dehulled seed varied with the calibre. This percentage was lower with calibre 1 (51.25 ± 2%). Calibres 2 and 3 had 69.00 ± 3% and 70.00 ± 7%, respectively of dehulled seeds. There was not significant difference between percentage of dehulled seeds of calibres 2 and 3. These two calibres were different to calibre 1 ($P \leq 0.05$). As reported De León *et al.* (1989) and Kristin (2008), the percentage of dehulled seed could be influenced by protein and carbohydrate contents. The highest percentage of dehulled seeds obtained with calibres 2 and 3 (**Fig. 5**) could be explained by the highest content of protein, carbohydrates and less content of seed coat in these calibres (**Table 1**). Seeds (calibre 1) with a high percentage of seed coat needed a long cooking time than those (calibre 2 and 3) with a low percentage of seed coat during the softening process (Rodríguez and Mendoza 1990; Reyes-Moreno *et al.* 1994). This information could be important to reduce the cooking time of *P. biglobosa* seed during the production of *Daddawa*.

## CONCLUSION

The results of this work showed that seeds samples contained an important level of nutrients which could be used as food supplements to reduce the deficiencies that are usually associated with most foods habits in developing countries. The calibration of locust bean seed could possibly reduce the cooking time of the seed. The distribution frequency curves of the axial dimensions tend to be normal. The amount of cotyledon increased with the mass of seed whiles the amount of seed coat decreased. Calibres 2 and 3 had a lower amount of seed coat and higher percentage of dehulled seed. There was no significant difference between them according to the mass of cotyledon, seed coats, amount of crude proteins, total carbohydrates, total lipids, ash and the percentage of dehulled seeds. With the respect to the percentage of dehulled seeds, calibres 2 and 3 could be used to reduce the cooking time of the seed during the softening process.

## REFERENCES

**AFNOR (Association Française de Normalisation)** (1982) *Recueil des Normes Françaises des Produits Dérivés des Fruits et Légumes. Jus de Fruits*, (1st Edn), AFNOR, Paris, France, 327 pp

**AFNOR (Association Française de Normalisation)** (1986) *Eaux - Méthodes d'Essais. Recueil de Norme Française*, AFNOR Paris (France), 400 pp

**Alabi DA** (1993) *Parkia biglobosa* an endangered species. *International Conference Proceeding on Lost Crops and Trees in Africa* **3**, 265-285

**Alabi DA, Akinsulire OR, Sanyaolu MA** (2005) Qualitative determination of chemical and nutritional composition of *Parkia biglobosa* (Jacq.) Benth. *African Journal of Biotechnology* **4 (8)**, 812-815

**AOAC (Association of Official Analytical Chemistry)** (1990) Preparation of methyl esters, boron trifluor method AOAC-IUPAC Method. In: *Official Methods of Analysis*, K. Helrich, E. (Ed.), (Fifteenth edition), Virginia (USA), pp 963-964

**Aviara NA, Haque MA** (2000) Moisture dependence of density, coefficient of friction and angle of repose of *guna* seed and kernel. *Journal of Engineering Applications* **2 (1)**, 44-53

**Bourely J** (1982) Observation sur le dosage de l'huile des graines de cotonnier. *Coton et Fibres Tropicales* **27 (2)**, 183-196

**Bricas N, Cheyns E** (1995) Incertitude et procédure de qualification des consommateurs urbains au Burkina; le cas d'un condiment traditionnel: le *soumbala*. In: Sylvander B, Allaire G (Eds) *Qualification des Produits et des Territories; Actes du Séminaire de Toulouse*, 2-3 October, p 19

**Campbell-Platt G** (1980) African locust bean (*Parkia* Species) and its west African fermented food product, *Dawadawa*. *Ecology of Food and Nutrition* **9**, 123-132

**Codex Stan 171** (1989) (Rev. 1 – 1995) Norme codex pour certains légumes secs.

**Codex Stan 66** (1981) (Rev. 1 – 1987) Norme codex pour les olives de table.

**Commission Canadienne des graines** (2007) Guide Officiel du Classement des Graines 1er août 2007

**Dakwa S, Sakyi-Dawson E, Diako C, Annon NT, Amoa-Awua WK** (2005) Effect of boiling and roasting the fermentation of soy beans into *dawadawa* (soy-*dawadawa*). *International Journal of Foods Microbiology* **104 (1)**, 69-82

**Dashak DA, Dawang ML, Lucas NB** (2001) An assessment of the proximate chemical composition of locally produced spices known as *Dadawa basso* and *Dadawa kalwa* from three markets in Plateau State of Nigeria. *Food Chemistry* **75**, 231-235

**De León LF, Bressani R, Elías LG** (1989) Effect of seed coat on the hard-to-cook phenomenon of common beans (*Phaseolus vulgaris*). *Archivos Latino Americanos de Nutricion* **39**, 405-407

**Devani MB, Shioshoo JC, Shal SA, Suhagia BN** (1989) Spectrophotometrical methods for micro determination of nitrogen in Kjeldahl digest. *Journal Association of Official Analytical Chemistry* **72 (6)**, 953-956

**Diawara B, Sawadogo L, Amoa-Awua WKA, Jakobsen M** (1998) Quality system for the production of *soumbala*. *HACCP System for Traditional African Fermented Foods* Soumbala. Taastrup: ISBN 87-90737-00-8 WAITRO Danish Technological Institute

**Dubois M, Gilles KA, Hamilton JK, Robert PA, Smith F** (1956) Colorimetry method for determination of sugar and related substances. *Analytical Chemistry* **28**, 350-356

**Dutta SK, Nema VK, Bhardawj RK** (1988) Thermal properties of gram. *Journal of Agricultural Engineering Research* **39**, 269-275

**Kone S** (2001) Fabrication du "Soumbala". *Infogate* Eschhborn Germany p 1-8. Available online: http://wwww.gtz.de/gate/

**Koziol MJ** (1990) Afrosimetric estimation of treshold saponin concentration for bitterness in quinoa. *Journal of the Science of Food and Agriculture* **54 (2)**, 211-220

**Kristin S** (2008) Tough beans: Which cooking liquids slow softening the most? In: Boretsky P (Ed) *Cooking and Foods Sciences Project Ideas. Science Buddies*, Lockheed Martin. Available online: http://www.sciencebuddies.org

**Marigo G** (1973) Méthode de fractionnement et d'estimation des composés phénoliques chez les végétaux. *Analysis* **59**, 106-110

**N'dir B, Lognay G, Wathelet B, Cornelius C, Marlier M, Thonart P** (2000) Composition chimique du *nététu*, condiment alimentaire produit par la fermentation des graines du caroubier africain *Parkia biglobosa* (Jacq.) Benth. *Biotechnologie, Agronomie, Société et Environment* **4 (2)**, 101-105

**Obizoba IC** (1998) Fermentation of African locust bean. Text on Nutri quality of plant fruits. *Post Harvest Research Unit*, Department of Biochemistry, University of Benin, Nigeria, pp 160-198

**Odunfa SA** (1985) African fermented foods. In: Wood BJB (Ed) *Microbiology of Fermented Foods* (Vol 2), Elsevier Applied Science, London, pp 155-191

**Odunfa SA** (1986) *Dawadawa*. In: Reddy NR, Pierson MD, Salunkhe DK (Eds) *Legume-based Fermented Foods*, CRC Press, Boca Raton, pp 173-189

**Ogunjimi LAO, Aviara NA, Aregbesola OA** (2002) Some engineering properties of locust bean seed. *Journal of Engineering* **55**, 95-99

**Okpala JO** (1990) Analysis of some macro nutrients and food substances in the matured fruits parts of *Parkia biglobosa. Nigeria Journal of Botany* **3**, 209-214

**Omafuvbe BO, Falade OS, Osuntogun BA, Adewusi SRA** (2004) Chemical and biochemical changes in Africa locust beans *Parkia biglobosa*) and melon (*Citrullus vulgaris*) seeds during fermentation to condiments. *Pakistan Journal of Nutrition* **3 (3)**, 140-145

**Osuntogun BA, Falade OS, Ugono O, Omafuvbe BO** (2004) The effect of seasoning salt and local condiment on mineral availability from two Nigerian vegetable. *Pakistan Journal of Nutrition* **3 (3)**, 146-153

**Ouoba LII, Rechinger KB, Barkholt V, Diawara B, Traoré AS, Jakobsen M** (2003) Degradation of proteins during the fermentation of African locust bean (*Parkia biglobosa*) by strains of *Bacillus subtillis* and *Bacillus pumilus* for production of *soumbala*. *Journal of Applied Microbiology* **94**, 396-402

**Paul AA, Southgate DAT** (1978) *McCance and Widdowson's The Composition of Food*, 4th revised and extended edition of MRC special report No. 297, HMSO, London

**Pons M, Frizman SM** (1996) Instrumental texture profile analysis with particular reference to gelled systems. *Journal of Texture Studies* **27**, 597-624

**Ratnayake RMS, Hurstst PL, Multon LD** (1999) Texture and the cell wall polysaccharides of butter squash "Delica" (*Cucurbita maxima*). *New Zealand Journal of Crop and Horticultural Science* **27**, 133-143

**Reyes-Moreno C, Cárabez-Trejo A, Paredes-López O, Ordorica-Falomir C** (1994) Physicochemical and structural properties of two bean varieties which differ in cooking time and the HTC characteristic. *Lebensmittel Wissencharft and Technologie* **23**, 331-336

**Rodier J** (1978) *L'analyse de l'Eau: Chimie Physisico-chimie, Bactériologie, Biologie* (6th Edn), Dunod Technique Paris, France, 1136 pp

**Rodríguez FM, Mendoza EMT** (1990) Physiochemical basis for hardseededness in *mung* bean (*Vigna radiata* (L.) Wilczek). *Journal of Agricultural and Food Chemistry* **38**, 29-35

**Statsoft Inc.** (1999) STATISTICA for windows. Tulsa, OK

**Walker AF, Kochhar N** (1982) Effect of processing including domestic cooking on nutritional quality of legumes. *Proceeding of the Nutritional Society* **41**, 41-51