

Chemical Composition and Functional Properties of Flours of Four Cultivars of Bambara Groundnut (*Vigna subterranea* L. Verdc)

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ABSTRACT

The partial chemical composition and some functional properties of flours of 4 cultivars of Bambara groundnut collected from the North and Littoral Provinces of Cameroon were investigated. Proximate analysis revealed that the seed flours are appreciable sources of crude proteins (16.36 - 21.36 g/100g DW), total lipids (6.89 - 8.07 g/100g DW) and minerals such as potassium (9.72-12.45 mg/g DW), phosphorus (2.83 - 2.93 mg/g DW), calcium (0.80 - 1.21 mg/g DW) and magnesium (0.40 - 0.50 mg/g DW). However, cultivars GWY and GPS from the North province had better chemical composition compared to YLB and YDV. For the antinutrients studied, the phytate content of seed flours was low (3.11 - 5.99 mg/g DW) with 30.97 to 59.79% of phytic phosphorus while total oxalate content was relatively high for the 4 cultivars (22.22 - 30.49 mg/g DW). Bambara groundnut showed good functional properties in general. Although their water and oil absorption capacities were relatively low (< 1.62 and < 1.02 g/g DW respectively), they exhibited high values of emulsifying activity (56 - 62 mL/100 mL), emulsion stability, foaming capacity (53 - 60 mL/100 mL) and foams stability.

Key words: Bambara groundnut (*Vigna subterranea*), composition, functional properties

List of abbreviation: DW (Dry weight);

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1- INTRODUCTION

Grain legumes are important sources of nutrients, especially proteins that are present in low amount in other crops. They are the main source of proteins for developing countries. Since their lysine content is very high, they allow to efficiently complete cereals were lysine is the limiting amino acid [1].

Bambara groundnut [*Vigna subterranea* (L.) verdc] also known as bambara pea or earth pea is an indigenous grain legume grown in dried parts of sub-saharian Africa. In most parts of Africa, it is the third most important legume after groundnut (*Arachis hypogaea*) and cowpea (*Vigna unguiculata*). This crop has many production advantages in that it can grow on poor soils with little rainfall, as well as produce substantial yields under better conditions [2, 3].

Bambara groundnut seeds are good sources of proteins (16-25%), and complex carbohydrate (50-60%) [4, 5]. Studies of its lipid composition revealed that linoleic and linolenic acids are present in good proportions (44 and 21% respectively). The amino acid composition showed that lysine is the major essential amino acid and the other (leucine, phenylalanine, histidine and valine) are present in good amount [6]. This legume can thus be used to enrich cereal products.

In this respect, functional properties of some grain-legume flours have been studied. Cowpea flour functionality has been investigated for the production of traditional food of good quality such as "akara" and "moinmoin" as well as other pastry and bakery products [7]. Similar investigations have been carried out on chickpea (*Cicer arietinum*) flours for production of enriched bakery and pastry products like bread, biscuits, cookies, doughnuts, crackers [8, 9, 10].

To the best of our knowledge, the functional properties of Bambara groundnut flours have not been well investigated. Bambara peas are used to prepare many dishes such as a steamed cooked paste locally known as "koki matobo" [4]. Good knowledge on functionalities of these flours can help to improve the use and valorisation of this locally available legume in traditional and other popular pastry and bakery products. The numerous Bambara pea varieties that have not yet benefited from research must be considered, since they can be different in composition and functionalities of their flours. This paper presents a partial chemical composition and some functional properties of flours of four Cameroonian popular cultivars of Bambara groundnut.

2- MATERIAL AND METHODS

2.1. Seeds collection and preparation of seed flours

Pods of 4 cultivars of Bambara groundnut chosen among the most common and most utilised were obtained from the August 2002 harvest in the North and Littoral provinces of Cameroon. Some characteristics of the 4 cultivars collected (GWY and GPS in Garoua;

YLB and YDV in Yabassi) are presented in table 1. Pods and seed coats were removed manually on well dried seeds and the resultant dehulled fractions were milled in a Victoria grain mill (Ref: 600009) grinder to pass through a 350 µm sieve.

Cowpea seeds also obtained from Garoua local market were milled in the same way and the flour was used as reference to compare functional properties.

2.2. Chemical composition

Proximate analysis : Proximate composition of the various flours was determined according to AOAC standard procedure [11]. Moisture content was determined on the basis of sample weight loss after oven drying at 105°C for 24h. Crude protein was measured by kjeldahl procedure using 6.25 as nitrogen conversion factor [12]. Total lipids were determined by 8 hours hexane-extraction in soxhlet apparatus. Crude fibres were determined as NDF by Van Soest & Wine [13] method. Ash was calculated as the weight remaining after incineration of the sample at 550°C in a furnace for 24 hours. Total carbohydrate was determined by difference after calculation of protein, fats, fibres and ash.

Minerals: Mineral analysis were carried out according to [14]. 1 g of dried sample was ashed, digested with HNO₃ (1mol/L), filtered and diluted to a final volume of 50 ml. Minerals (except phosphorus) were assayed by atomic absorption spectrophotometry. Phosphorus was determined colorimetrically using phospho-vanado-molybdate yellow complex.

2.3. Antinutrients (total oxalate and phytate)

Total oxalate was extracted in 0.75 g sample with HCl (6 mol/L) and measured by oxidation of oxalic acid by 0.05 mol/L potassium permanganate under heat and in the presence of sulphuric acid as described in [15].

Phytic acid was determined by the method of [16] with minor modification. Phytate was extracted from 0.5 g sample with 25 mL TCA (3g/100mL) solution and precipitated as ferric phytate. The precipitate was then separated by centrifugation and washed with 0.5 mol/L HCl. Its phosphorus content was determined [after hydrolysis with 10 mL concentrated HNO₃ (d = 1.4)] by the molecular absorption spectrophotometry of the phospho-vanado-molybdate complex at 430 nm. The phytic acid content was then calculated from the phosphorus content.

2.4. Functional properties

Water Absorption Capacity (WAC) and Water Solubility Index (WSI)

WAC was determined by the method of [17] while WSI was determined by the method of [18]. 1 g flour sample (Mo) was suspended in 10 mL of distilled water and mixed on a mechanical shaker for 30 min. The suspension was then centrifuged at 2100 g for 30

Table 1: Description of the four Bambara groundnut cultivars collected.

	Cultivars	GWY	GPS	YLB	YDV
	<i>Colour</i>	cream	brown	light brown	brown violet
Pods	<i>Hardness</i>	hard	slightly hard	very hard	not hard
	<i>Colour</i>	White with black eyes	purple with violet spots	light brown	dark violet
Seeds	<i>Size: mean diameter (cm)</i>	11.04 ± 0.91	10.97 ± 0.56	11.61 ± 1.03	9.68 ± 1.24
	<i>100 seeds weight (g)</i>	90.85	73.34	77.67	57.20

min. The pellet was weighed (M_2), dried at 105°C for 24 h and weighed (M_1). The water absorption capacity (WAC) and apparent water absorption capacity (AWAC) were then calculated as follow :

$$WAC = \frac{(M_2 - M_1)}{M_0} \times 100 \quad AWAC = \frac{M_2 - M_0}{M_0} \times 100$$

While the WSI was calculated by $WSI =$

$$\frac{M_0 - M_1}{M_0} \times 100$$

Oil Absorption Capacity (OAC) and Hydrophilic/Lipophilic ratio (H/L)

Oil absorption capacity (OAC) was assayed based on [19]. 5 mL of refined palm oil (Palm'or[®], of Socapalm-Cameroon) was added to 0.5 g flour in a 10 mL centrifuge tube and mixed mechanically with a shaker. The mixture was allowed to stand at 25°C for 30 min before centrifuging (2100 g for 30 min). Free oil was discarded and the percentage of absorbed oil determined by weight difference.

The hydrophilic/lipophilic ratio was calculated as H/L

$$= \frac{AWAC}{OAC}$$

Emulsifying Activity (EA) and Emulsion Stability (ES)

Emulsifying Activity and Emulsion Stability was determined according to [20]. In this method, 1g of sample

was mixed with 3 mL water and 3 mL refined palm oil (Palm'or[®] of Socapalm-Cameroon) in a graduated tube. The mixture was homogenised for 10 min on a vortex mixer and centrifuged at 2100 g for 20 min. The emulsion volume was measured and the emulsifying activity was expressed as percentage of the emulsified layer volume of the entire layer in the centrifuge tube. To determine the emulsion stability, the prepared emulsions were heated at 80°C for 30 min, cooled at room temperature and centrifuged at 2100 g for 20 min. Emulsion stability was expressed as percentage of the remaining emulsified layer volume of the original emulsion volume.

Foaming Capacity (FC) and Foam Stability (FS)

50 mL of 2% (2g/100mL) flours suspension was blended at moderated speed in a household blender (Braun, Germany) for 2 min and foam volume recorded. Foaming capacity was expressed as the percentage increase in foam volume measured at 20 s. Foam stability was determined according to residual foam volume at 20, 40 and 60 min after blending.

Gelation Capacity (GC)

Gelation capacity was determined as [21]. Eight flour suspensions of 4, 6, 8, 10, 12, 14, 16 and 18 g/100 mL were prepared. 5 mL of these suspensions were introduced into a test tube and placed in a boiling water bath for 1h, followed by rapid cooling under cold running tap water. The tubes were further cooled for 2 h

Table 2: Chemical composition of Bambara groundnut flours (g/100g dry weight flour)

Components	Bambara groundnut flours			
	GWY	GPS	YLB	YDV
Moisture *	10.55 ± 1.40 ^a	10.81 ± 0.39 ^a	11.11 ± 0.28 ^a	11.69 ± 1.38 ^a
Proteins	21.36 ± 0.25 ^a	21.13 ± 0.49 ^a	18.83 ± 0.30 ^b	11.36 ± 0.41 ^c
Crude Fats	8.07 ± 0.29 ^a	7.49 ± 0.27 ^a	7.71 ± 0.01 ^b	6.89 ± 0.25 ^c
Fibres	3.47 ± 0.42 ^a	3.68 ± 0.67 ^a	3.29 ± 0.71 ^a	4.14 ± 1.12 ^a
Carbohydrate (fibre excluded)	64.37 ± 1.76 ^a	64.84 ± 3.30 ^a	67.55 ± 1.44 ^a	69.45 ± 3.42 ^a
Ash	2.73 ± 0.28 ^a	2.85 ± 0.23 ^a	2.61 ± 0.06 ^a	3.15 ± 0.64 ^a

Values are means ± standard deviation of 3 determinations expressed as dried weight. Values with different letters superscript within the same row are significantly different (P<0.05).

* in g/100g

at 4°C. The gelation capacity was taken to be the concentration which prevented the sample (paste) from slipping when the tube was inverted.

2.5. Statistical analysis

All determinations were done in triplicate and results were expressed as the mean values \pm standard deviation. To ascertain the significance among means of samples, student t-test was applied and $P < 0.05$ was used to establish significant difference.

3. RESULTS AND DISCUSSION

3.1. Chemical composition

The moisture, protein, fat, fibre, carbohydrate and ash contents of the flours are shown in table 2. Protein content ranges from 16.36 to 21.36 g/100 g dry weight (DW) and GWY and GPS flours have higher protein content ($P < 0.05$) than YLB and YDV flours. With this high protein content, Bambara groundnut can be a valuable source of protein supplement in food. These results agree with those reported in [22] who found a protein content of 15.9 to 21.5 for some Ghanaian cultivars of Bambara groundnut. Fat content range from 6.89 (YDV) to 8.07 g/100 g flour (GWY). This relatively high fat content is of interest since the fat content of most grain legumes does not exceed 3 g/100g DW [1]. The amount of fibre and other carbohydrates in Bambara groundnut flours is also appreciable.

Table 3 indicates the mineral composition of the various Bambara pea flours. The flours contain high level of potassium (9.72 – 12.40), phosphorus (2.82 – 2.93) and calcium (0.80 – 1.21 mg/g DW). The potassium content is higher than that of cowpea (7.77). Magnesium, zinc and iron were present at low level. This mineral composition is good compared to that of other grain legumes [23].

3.2. Antinutrients (oxalate and phytate)

Total oxalate and phytate contents of the various flours are shown in table 4. The phytic acid content that range from 3.10 to 5.99 mg/g DW was lower for the YLB

and YDV flours and there was a significant difference ($P < 0.05$) among them. This low phytic acid content, comparable to that of *Pisum sativum* (4.72 mg/100 g) determined in [24] was lower than that of most grain legumes [25]. The percentage of phytic phosphate (30.97 to 59.79% of total phosphate) was lower than the average of 78.2% for most grain legumes [25]. Phosphorus in Bambara groundnut can therefore be available as well as other minerals since phytic acid forms insoluble compounds with divalent cations like Zn, Cu, Fe, Mn, Ca reducing bioavailability [26].

Unlike phytate, the total oxalate content was high (22.22 – 30.49 mg/g flour) and there was no significant difference among samples. This high oxalate content can reduce the availability of calcium. However since only soluble oxalates are really toxic, it will be interesting to determine the content of these soluble oxalates in Bambara groundnut flours. [27] found higher oxalate content in some varieties of soybean (6.7- 35.0 mg/g).

3.3. Functional properties of flours

Functional properties of Bambara groundnut and cowpea flours are shown in table 5.

Water absorption capacity (WAC) and water solubility index (WSI)

WAC did not differ a lot among Bambara groundnut flours (1.51 to 1.63 g/g flour) and was lower ($P < 0.01$) than that of cowpea flour (2.47 g/g flour). This WAC is also lower than that of other grain legumes such as *Phaseolus vulgaris* (3.0), *Phaseolus aureus* (2.9), *Phaseolus lunatus* (2.65) and *Canavalia ensiformis* (3.80 g/g) [28, 29]. This difference can be due to the particle size ranging from 150 to 280 μm in our study and thinner in others). In fact, [31] found out that for cowpea flour, WAC increase from 1.62 (in 297 μm fraction) to 2.40 g/g (in 149 μm fraction). We can thus expect an increase in WAC of Bambara groundnut flours with decreased milling size. Processing technology on Bambara groundnut must be selected to improve water absorption.

WSI did not vary too much for Bambara

Table 3: mineral composition of Bambara groundnut flours (mg/g DW flours)

Minerals	Bambara groundnut flours			
	GWY	GPS	YLB	YDV
Ca	0.80 \pm 0.08 ^a	0.99 \pm 0.06 ^b	1.20 \pm 0.09 ^c	0.91 \pm 0.09 ^a
P	2.93 \pm 0.10 ^a	2.82 \pm 0.10 ^a	2.82 \pm 0.10 ^a	2.82 \pm 0.10 ^a
K	11.53 \pm 0.31 ^a	12.31 \pm 0.46 ^a	9.72 \pm 0.33 ^b	12.45 \pm 0.55 ^a
Na	0.25 \pm 0.02 ^a	0.23 \pm 0.02 ^a	0.27 \pm 0.03 ^a	0.22 \pm 0.02 ^a
Mg	0.40 \pm 0.01 ^a	0.50 \pm 0.07 ^b	0.43 \pm 0.03 ^c	0.44 \pm 0.07 ^c
Zn	0.05 \pm 0.00 ^a	0.06 \pm 0.00 ^a	0.07 \pm 0.00 ^b	0.07 \pm 0.00 ^{ab}
Fe	0.09 \pm 0.01 ^a	0.04 \pm 0.01 ^b	0.08 \pm 0.01 ^a	0.03 \pm 0.00 ^b

Values are mean \pm standard deviation of 3 determinations expressed as dry weight. Values with different letters superscript within the same row are significantly different ($P < 0.05$).

Table 4: Total oxalate and phytate contents of Bambara flours (mg/g flours)

Parameters	Bambara groundnut flours			
	GWY	GPS	YLB	YDV
Total oxalate	22.22 ± 2.85 ^a	28.36 ± 7.53 ^{ab}	30.49 ± 2.87 ^b	30.35 ± 2.86 ^b
Phytic acid	4.47 ± 0.24 ^a	5.99 ± 0.38 ^b	3.10 ± 0.13 ^c	3.85 ± 0.23 ^d
% of phytic phosphorus	42.98 ± 0.82 ^a	59.79 ± 1.64 ^b	30.97 ± 0.22 ^c	38.47 ± 0.88 ^d

Values are mean ± standard deviation of 3 determinations expressed as dry weight. Values with different letters superscript within the same row are significantly different (P<0.05).

groundnut flours (35 – 39g /g flour). However, the WSI of GWY (39.1) and GPS (39.6) were higher than that of YLB (35.1) and YDV (35.5) while that of cowpea was lower (30.8 g/g flour).

Oil absorption capacity (OAC) and hydrophilic/lipophilic ratio (H/L)

OAC of Bambara pea flours ranged from 0.80 to 0.99 and was not too different from that of cowpea (1.02 g oil/g flour). Very high OAC have been reported for *C. ensiformis* (3.15), *P. sativum* (2.9), *P. vulgaris* (2.2) and *P. aureus* (2.1 g/g) but also low values for cowpea (0.45 - 0.75) and soy bean (0.56) flours [28, 30, 29]. This parameter that is said to be linked to non polar amino acid residues and useful for flavour retention and improvement of palatability seems to vary much among grain legumes. The low OAC can be considered as a great advantage since preparations with Bambara groundnut flour will absorb less oil and will thus be less expensive.

Bambara groundnut flours absorb approximately equal amount of oil and water (H/L = 0.99 - 1.24). They can thus be used in food emulsion preparation as confirmed by the emulsifying activity.

Emulsifying activity (EA) and Emulsion stability (ES)

Bambara groundnut flours exhibited high EA values (56 to 62 mL/100mL) compared to that of cowpea flours (51 mL/100 ml) . This indicates the capability of Bambara pea proteins to be soluble, to diffuse and ad-

sorb at the oil/water interface. These EA values were greater than that of *P. lunatus* and *C. ensiformis* flours (41.78 - 52.46) and were comparable to that of protein isolates of some legumes [29]. Thus protein isolates or concentrates of Bambara groundnut could exhibit high EA.

Unlike EA, emulsions stability was variable among Bambara groundnut flours, with highest values (69.58%) for GWY and lowest (6.43%) for YDV. However, emulsion based on bambara groundnut flours (excepted YLB) were more stable than that of cowpea (16.85%). These results reveal that flours of Bambara peas can be effective emulsifying agent that can be applied in products such as pastry and sausage. However, some cultivars may perform better than others in ES.

Foaming capacity (FC) and Foams stability (FS)

Both Bambara groundnut and cowpea flours showed high FC (53.33 to 60.40 mL/100 mL) and there were significant difference among them . These results are comparable to those of protein isolates of *P. lunatus* and *C. ensiformis* in acid (pH=2) and alkaline (pH=8-10) conditions [29]. The flours developed high initial foam volume and maintained their relatively coarse structure throughout the 1 hour period (Figure 1). Foams of Bambara groundnut flours are more stable than that of cowpea flour (Figure 1). Given the important role of proteins in formation and stabilisation of foams, Bambara groundnut proteins may be better foam

Table 5: Functional properties of Bambara groundnut and cowpea flours

Parameters	Bambara groundnut flours				Cowpea flour
	GWY	GPS	YLB	YDV	
AWAC (g/g)	0.99 ± 0.02 ^a	0.92 ± 0.03 ^b	0.97 ± 0.05 ^a	0.99 ± 0.01 ^a	1.71 ± 0.70 ^c
WAC (g/g)	1.63 ± 0.04 ^a	1.51 ± 0.05 ^b	1.51 ± 0.1 ^{ab}	1.54 ± 0.03 ^b	2.47 ± 0.10 ^c
WSI (g/g)	39.1 ± 00.3 ^a	39.6 ± 0.4 ^a	35.1 ± 1.2 ^b	35.5 ± 0.7 ^b	30.8 ± 0.8 ^c
OAC (g/g)	0.99 ± 0.03 ^a	0.92 ± 0.03 ^{ab}	0.88 ± 0.05 ^a	0.80 ± 0.03 ^b	1.02 ± 0.02 ^c
H/L	1.003 ± 0.059 ^{ac}	0.994 ± 0.062 ^a	1.106 ± 0.059 ^a	1.243 ± 0.060 ^b	1.678 ± 0.596 ^c
EA (mL/100 mL)	59.41 ± 6.60 ^a	56.08 ± 3.08 ^a	62.29 ± 6.02 ^a	56.13 ± 3.21 ^a	51.10 ± 4.38 ^a
ES (%)	69.58 ± 9.02 ^a	26.41 ± 5.93 ^b	37.82 ± 9.04 ^b	6.43 ± 1.25 ^c	16.85 ± 1.65 ^d
FC (mL/100 mL)	60.40 ± 0.56 ^b	58.00 ± 7.27 ^{ab}	53.33 ± 7.07 ^b	58.66 ± 10.06 ^b	56.00 ± 5.65 ^b
GC (g/100 mL)	18	16	19	18	15

Values are mean ± standard deviation of 3 determinations expressed as dry weight. Values with different letters superscript within the same row are significantly different (P<0.05).

stabilisers than cowpea proteins.

Gelation capacity (GC)

The minimum gelation concentrations for Bambara groundnut flours were 16 to 18 g/100 mL water. Cowpea flour had a higher capacity to form gels after heating (15 g/100 mL). These concentrations are however higher than the 8g/100mL observed in peas (*Pisum sativum*) [24]. The high gelation concentration in our study can be due to particle size. Our Bambara groundnut flours had greater particle size compared to flours used by these authors. This particle size affects the ability of water to penetrate flours particles and to either absorb or carry away soluble components [30].

CONCLUDING REMARKS

Bambara groundnut flours are good sources of proteins, lipids, carbohydrates and minerals. Their phytate content is relatively low. GWY and GPS cultivars from Garoua showed a better nutritive value than YLD and YDV. Functional properties of Bambara groundnut flours are interesting. Their water and oil absorption capacities are relatively low but their capacity to produce and stabilise emulsions and foams are in most cases greater than that of other grain legumes. Studies must be carried out to increase water absorption that may be a limiting factor in processing with other flours.

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