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Influence of Morphological Variability on Nutritional and Technological Characteristics of Flours from Cowpea (*Vigna unguiculata* L., 1843) Grown in Côte d'Ivoire

Souleymane Traore, Ahou Leticia Loukou, Adouko Edith Agbo, Mampeu Carine Zah, Hadja Mawa Fatim Diabagate*, Fatoumata Camara, Kouakou Brou

Food Sciences and Technology Department, Laboratory of Nutrition and Food Safety,
Nangui Abrogoua University, Abidjan, Côte d'Ivoire
*Corresponding author: fatidiam@yahoo.com

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Abstract In Côte d'Ivoire, from leaves to seeds, cowpea were used in different forms for preparation of several dishes. For better valorization, this study aimed to evaluate the influence of morphological variability on the nutritional and technological characteristics of flours from cowpea seeds. The study was carried out on the red and white grains of cowpea collected at the market of Korhogo and Abidjan. After classification according to their size, shape and color, the grains were ground to obtain flour. The biochemical, nutritional and functional properties parameters were performed on the flours. The results showed high dry matter contents (> 85 %) in all flours whatever the color and size of grains. The red varieties flours, large and small size, were higher total carbohydrates contents (71.47% and 67.20%), and protein content (18.50 ± 0.23% and 13.33 ± 7.69%) than white varieties. In addition, the amino acid profile were dominated by methionine followed by threonine and lysine, which were showed the higher contents in flours of red varieties. The lipid contents of all the flours was less than 3%, on the other hand, the energy was higher than 340 kcal / 100g. The red and white varieties of large size were higher fiber with respective values of 25.45 ± 0.30% and 26.13 ± 0.30%. The results of functional properties showed that flour of the red varieties were higher water absorption capacity than white varieties. On the other hand, all flours were similar absorption capacity in Dinor oil whatever the color and size. The nutrient profile by the determination of scores SAIN > 5 and LIM <7.5 classified red and white cowpea in food of group 1, recommended foods for health. Whatever the morphological variabilities, the flours from red and white Cowpea could be recommended as a local product in the formulation in infant food.

Keywords: *morphological variability, Grains, flours, nutritional profile, Cowpea, proteins, anti-nutritional factors*

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1. Introduction

Legumes or vegetable play a crucial role in a healthy and balanced diet. According to [1], legumes varies widely in terms of their biochemical composition and overall flavor. Their unique qualities make them perfect for sustainable agriculture. A recent study by [2] showed that legumes enrich the soil with nitrogen and constitute a considerable agricultural interest group in crop rotations and associations. According to [3], there are various kinds and they are mostly edible such as beans, soybeans, alfalfa, lentils, peanuts, peas, but some of one are not such as clover.

The annual world bean production in 2012 was 23.6 million tonnes [4]. Beans have occupied a prominent place as a staple food in sub-Saharan Africa, particularly in the arid savannas of West Africa [5]. Bean species are very numerous and mostly belong to warm regions of the globe. According to [6], the bean species were distributed in about 750 genera. The genera Phaseolus in the Americas and Vigna (cowpea) in various parts of Asia and Africa are the most widespread [1,7]. The annual cultivated area in the world amounts to more than 11.8 million hectares, of which 10.7 million hectares are in West Africa [8]. Global cowpea production was estimated at 6 million tonnes. The main producer is Nigeria with 2.5 million tonnes followed by Niger with 735.000 tonnes [9]. Nutritionally, cowpea is a source of protein, vitamins and minerals for human food [10]. In addition, its proteins are rich in essential amino acids such as lysine, leucine and phenylalanine [11,12]. Despite several studies, including those of [13,14], who showed the importance of beans, the influence of morphological variability of its grains on the nutritional profile remains unknown.

Nutrient Profile is a classification of foods based on their nutritional composition. The best food profiling system currently is the determination of the scores SAIN and LIM. [15] first described this system. This method was based on two indicators, previously developed to study the relationship between nutritional quality and the cost of food [16]. In addition, the nutritional profiling method has been tested on more than 600 foods listed in the Ciqual-Afssa food composition table [17,18]. Given to the great varietal and morphological diversity of cowpea grains and their importance in food, it would be interesting to know if the morphological variability of cowpea grains has an influence on its nutritional and technological characteristics. In other words, determine a correlation between the morphological variability and the nutrient content of cowpea grains. The objective of this work was to determine the influence of morphological variability on the nutritional and technological characteristics of flours from cowpea grains.

2. Material and Methods

2.1. Material

Legumes used in this study are the two (2) varieties of cowpea (*Vigna unguiculata*). The white variety (large and small size) and the red variety (large and small size) were collected at the market of Korhogo and Abidjan. The choice of white and red grains of cowpea was due to their availability and high consumption in Africa and also in Côte d'Ivoire.

2.2. Methods

2.2.1. Cowpea Flours Production

2.2.1.1. Sorting and winnowing

The beans (cowpea) of each variety collected were winnowed and sorted to remove debris (pebbles, bad seeds, dry leaves). The winnowing was done using a van and the sorting was done by hand.

2.2.1.2. Morphological classification of cowpea seeds

The morphological study of each cowpea variety was made by measuring the length of seeds. About 1000 cowpea grains of each variety were measured using a caliper. The measured grains were classified according to their size, shape and color.

2.2.1.3. Flour production

The different batches of grains were washed with distilled water and dried in an oven (Memmert brand) at 45°C for 24 h. After drying, the cowpea seeds were ground in a Binatone Model Number BLG-451 brand mixer. The flours obtained were sieved to remove large particles in a sieve with a diameter of 250 µm and were stored in airtight containers for analysis.

2.2.2. Physico-chemical Characteristics of Flours from Cowpea Grains

Moisture content

Moisture was determined by drying the sample at 105°C for 24 h according to [19]. Samples were then cooled in desiccators and weighed. The loss of weight was expressed as a percentage of the initial weights of the samples give their moisture content.

Protein content

Protein was determined by determination of total nitrogen according to the Kjeldahl method [20]. Under the action of NAOH and after sulfuric mineralization in the presence of catalyst ($CuSO4$), ammoniac formed was neutralized. The ammonia in the sample solution was then distilled into the boric acid until it changed completely to bluish green. The distillate was then titrated with 0.1 N HCl solutions until it became colorless. The percent total nitrogen and the crude protein were calculated using a conversion factor of 6.25.

Fat content

Fat was determined based on the Sohxlet extraction method of [19]. Five gram (5.0 g) of the sample was introduced into a cartridge of Whatman. An empty flask reweighed and containing 60 ml of hexane was placed on the heating block of the Soxhlet apparatus and heated at 110°C. After 6 hours of extraction, the flask was removed from apparatus and then the solvent was evaporated on a Rotary Evaporator. The flask containing the fat and residual solvent was placed on a water bath to evaporate the solvent followed by further drying in an oven at 60°C for 30 min to completely evaporate the solvent. It was then cooled in desiccators and weighed. The fat obtained was expressed as a percentage of the initial weight of the sample.

Total carbohydrate content

Total carbohydrate content is determined by difference method

$$[100\% - (\%\ moisture + \%\ ash + \%\ fat + \%\ protein).$$

Energy content

Energy is calculated with 4 kcal / g carbohydrates, 4 kcal/g protein and 9 kcal / g lipids according to [21].

$$Energy = \begin{bmatrix} 9\ x\ \%\ Fat + 4\ x\%\ Protein \\ +4\ x\ \%\ Carbohydrates \end{bmatrix}$$

Ash content

Ash was obtained after incineration at 550°C for 6h according to [19]. Sample (5g) was weighed into a previously dried and weighed porcelain crucible. The crucible with its content was placed in a furnace at 550°C for 6h. After cooling in desiccators, the crucible with its content was weighed. The weight of the ash was expressed as a percentage of the initial weight of the sample.

Mineral content

Mineral content are determined by atomic absorption spectrophotometry. Ash (0.1g) is weighed in platinum crucibles to which, was added 1 ml of distilled water. In each crucible, 5 ml of hydrofluoric acid 50% and 2 drops of sulfuric acid (v / v) were added. The whole, well homogenized and heated at 100°C until fully evaporated. The residue obtained was dissolved in 10 ml of 50% hydrochloric acid. Solution was left to stand for 10 minutes on the bench and the final volume was brought to 100 ml.

Ethano-soluble total sugars content

The ethano-soluble total sugars were measured according to the method of [22] using phenol and concentrated sulfuric acid. Extract ethano - soluble (100 µl) was put in the test tube. The (200 µl) of phenol (5% w / v) and 1 ml of concentrated sulfuric acid were added successively to the reaction medium. After homogenization, the optical density was determined at the spectrophotometer (GENESYS 5) at 490 nm against a control containing no sweet extract. Optical densities were converted to total sugars by a calibration line obtained from a glucose solution (1 mg / ml).

Ethano-soluble reducing sugars content

Ethano-soluble reducing sugars are determined by the method of [23]. The mixture was heated in boiling water bath for 5 minutes and cool for 10 minutes at room temperature. About 3.5 ml of distilled water are added to the reaction medium. The optical density was performed at 540 nm with a control. This value was converted into mg of reducing sugars by means of the calibration curve obtained from glucose solution at 1 mg / ml.

Fiber content

Fibers content were determinated according to the method described by [19]. About 50 mL of sulfuric acid (0.25 N) was added in to 2 mg of flour. The solution obtained was homogenized and boiled for 30 min under reflux. Then 50 ml of sodium hydroxide (0.31 N) were added and heated at boiling for 30 min under reflux. The extract obtained was filtered on Whatman filter paper and the residue was washed several times with hot water until complete elimination of the alkalis. After removal, the residue was dried in an oven at 105°C for 8 h, cooled in a desiccator and weighed. The residue obtained was incinerated in the oven at 550°C for 3 h, cooled in a desiccator and the ashes were weighed.

2.2.3. Phytomicronutrient Content

Total polyphenol content

Total polyphenols were estimated by the Folin-Ciocalteu method [24]. The extraction of total phenolic compounds is done according to the technique described by [25]. About one (1) g of cowpea flour is weighed in a centrifuge tube. Ten (10) ml of 80% (v / v) methanol containing 8% (v / v) formic acid is added thereto. The mixture is homogenized and incubated at 37 ° C in a water bath for 30 min then centrifuged at 8000 revolutions / min for 10 min. The supernatant is taken and stored in a 50 ml Erlenmeyer flask. The pellet is taken up in 10 ml of 80% (v / v) methanol containing 8% (v / v) formic acid. The homogenized mixture is centrifuged under the same conditions as above. The new supernatant obtained is poured into the 50 ml Erlenmeyer flask. The phenolic compounds contained in the supernatants are concentrated through the use of a sand bath which promotes the evaporation of methanol from the medium. The content of phenolic compounds is calculated from the calibration curve.

Flavonoids content

The flavonoids content was carried out according to the method described by [26]. Sample extract (0.5 ml) was introduced into a tube. At this volume, was successively added 0.5 ml of distilled water, 0.5 ml of aluminium chloride with 10%, 0.5 ml of acetate of potassium 1N and 2 ml of distilled water. The tube was left at rest during 20 min with the darkness and the optical density is read to 415 nm against a blank. A range was established from a stock solution of quercetin (0.1 mg / mL) under the same conditions as the test and the amount of flavonoids in the sample was determined

2.2.4. Antinutrient Factor Content

Tannin content

Tannins was carried out according to the method described by [27]. One (1) ml of methanolic extract is placed in a test tube and 5 ml of vanillin reagent is added. The tube is left to stand for 20 min in the dark and the optical density (OD) is read at 500 nm against a blank. The amount of tannins in the samples is determined using a standard range established from a stock solution of tannic acid (2 mg / ml) under the same conditions as the test.

Phytate content

The quantification of the phytates was based on the method of [28]. The mixture obtained is left to stand for one hour before reading the optical density (OD) at 470 nm against a blank. A standard range is established from a stock solution of Mohr's salt (10 µg iron / ml) under the same conditions as the test for the determination of the amount of phytate-ferric in the sample.

2.2.5. Functional Properties Measurement

- Water absorption capacity (WAC) and water solubility index (WSI). WAC and WSI were evaluated according to [29,30] methods, respectively. About 1 g of flour were mixed with a 10 ml of distilled water in a centrifuge tube and shaken for 30 min in a KS10 agitator. After shaking, the mixture was centrifuged (Ditton LAB centrifuge, UK) at 4500 rpm for 10 min. The resulting sediment was weighed and then dried at 105°C to constant weight. The capacity for water absorption was expressed in grams of water per g of sample.
- Oil absorption capacity (OAC) was evaluated according to [31] methods. About 1 g of flour were mixed with a 10 ml of sunflower oil in a centrifuge tube and shaken for 30 min in a KS10 agitator. The mixture was kept in a water bath (37°C) for 30 min and centrifuged (Ditton LAB centrifuge, UK) at 4500 rpm for 10 min. The resulting sediment was weighed and then dried at 105°C to constant weight. The capacity for oil absorption was expressed in grams of oil per gram of sample.

2.2.6. Nutritional Profile by the SAIN, LIM System

The nutritional profile used was the SAIN and LIM system described by [15]. The SAIN refers to the favorable aspects of the food (qualifying nutrients) and the LIM refers to the unfavorable aspects (disqualifying nutrients). A food has a good profile when its SAIN is high and its LIM is low.

SAIN calculation formula is as follows:

$$\mathrm{SAIN} = \frac{\frac{\left[\frac{\text{Vitamin C}}{\text{RNI Vitamin C}} + \frac{\text{Iron}}{\text{RNI Iron}} + \frac{\text{Calcium}}{\text{RNI Calcium}} + \frac{\text{Protein}}{\text{RNI Protein}} + \frac{\text{Fiber}}{\text{RNI Fiber}}\right]}{5} \times 100}{\text{Energy}} \times 100$$

RNI (Recommended Nutritional Intake)

The LIM calculation formula is as follows:

$$\mathrm{LIM} = \frac{\frac{\text{Na}}{3153} + \frac{\text{SFA}}{22} + \frac{\text{Added sugar}}{50}}{3} \times 100$$

SFA= Saturated fatty acid.

These two values plotted on a graph used to classify foods into four groups. It considers two acceptability thresholds (SAIN> 5 and LIM <7.5):

1. Foods recommended for health (SAIN> 5 and LIM <7.5)
2. Neutral foods (SAIN < 5 and LIM <7.5)
3. Foods recommended in small quantities or occasionally (SAIN> 5 and LIM> 7.5)
4. Foods to limit (SAIN < 5 and LIM> 7.5).

2.2.7. Statistical Analyses

Results made in triplicate measurements were expressed as means with standard deviation. A one-way ANOVA was performed and means were separated using Tukey test ($p \leq 0.05$) or Dunnett test ($p \leq 0.05$) with Statistica 7.1 software. Graphical representations were made with Microsoft Word and Microsoft Excel.

3. Results

3.1. Morphological Classification of Seeds

Based on the data obtained, two groups of morphological variability of bean kernels were identified.

Bean grains of small sizes (3 mm ≤ small size ≤ 8 mm; n = 1000),

Bean grains of large sizes (8 mm <large sizes ≤ 12 mm; n = 1000).

The codes chosen to identify the flours from small and large bean kernels are:

Fgrp: Flour from small size red beans ([3mm; 8mm])

Fgrg: Flour from large size red beans (] 8mm; 12mm])

Fgbp: Flour from small size white beans ([3mm; 8mm])

Fgbg: Flour from large size white beans (] 8mm; 12mm])

For each group, approximately 1000 grains were selected for biochemical analyzes.

3.2. Biochemical Composition of Cowpea Flours

Biochemical composition of the different flour are presented in Table 1. The dry matter contents of flours from large size cowpea varieties (Fgbg) 87.87 ± 0.03% and (Fgrg) 88.01 ± 0, 19% was significantly higher compared to those from small size varieties (Fgbp) 86.43 ± 0.14% and (Fgrp) 86.59 ± 0.07%. The results showed that the red varieties (Fgrg) and (Fgrp) have higher protein content with the values of 18.50 ± 0.23% and 13.33 ± 7.69% respectively compared to the white varieties. The total carbohydrate contents varies from 63.78% to 71.47% with a preponderance in red flours (Fgrg) 71.47% and (Fgrp) 67.75%. Results also showed high fiber contents in large size of white and red varieties (Fgbg) 26.13 ± 0.30% and (Fgrg) 25.45 ± 0.30 compared to those of the small sizes (Fgbp and Fgrp). On the other hand, ash contents are similar in all the flours whatever the characteristics morphology. Concerning the energy values, the flours made from cowpea grains studied have energy contents above 340 Kcal / 100g.

3.3. Mineral composition

The mineral contents of different flours studied are presented in Table 2. The results showed significant difference in minerals between the different flours whatever the size and colors. The most important minerals in those flours are potassium, phosphorus and magnesium. The contents of potassium, phosphorus and calcium were significantly high in flours of red varieties (Fgrg and Fgrp) compared to those of white varieties (Fgbg and Fgbp). On the other hand, magnesium content has higher in flours from large size beans (Fgrg and Fgbg) than those from small size beans (Fgrp and Fgbp).

Table 1. Biochemical composition of the flours

Chemical parameters	Flours			
	Fgbg	Fgrg	Fgrp	Fgbp
Dry matter (%)	87.87 ± 0.03[a]	88.01 ± 0.19[a]	86.59 ± 0.07[b]	86.43±0.14[b]
Proteins (%)	11.21 ± 0.24[d]	18.50 ± 0.23[a]	13.33 ± 7.69[b]	12.60 ± 0.24[c]
Lipids (%)	1.76 ± 0.02[b]	1.84 ± 0.05[b]	2.37 ± 0.03[a]	1.79 ± 0.04[b]
Glucid total (%)	63.93±0.01 [d]	71.47±0.01 [a]	67.75±0.02 [b]	65.20±0.02 [c]
Sugar total (%)	6.90 ± 0.38[a]	5.67 ± 0.57[b]	5.37 ± 0.08[c]	5.24 ± 0.04[d]
Sugar reducing (%)	0.12 ± 0.06[b]	0.14 ± 0.02[a]	0.07 ± 0.01[c]	0.05 ± 0.01[d]
Fibers (%)	26.13 ± 0.30[a]	25.45 ± 0.30[a]	24.60 ± 0.48[b]	23.33 ± 0.41[b]
Ash (%)	3.43 ± 0.11[a]	3.74 ± 0.01[a]	3.69 ± 0.10[a]	3.73 ± 0.19[a]
Energy (Kcal/100g)	346.54	346.28	343.45	340.42

Values are means ± standard deviations of three measures (n = 3). The same letter subscripted in the same line indicates that there is no significant difference between samples for the parameter concerned ($p<0.05$).

Fgbg: flour from large size white beans; **Fgrg:** flour from large size red beans; **Fgrp:** flour from small size red beans; **Fgbp:** flour from small size white beans.

Table 2. Calcium, magnesium, phosphorus, potassium, iron and sodium content

Mineral (mg/100g)	Flours			
	Fgbg	Fgrg	Fgrp	Fgbp
Calcium	121 ± 0.69[c]	246 ± 1.42[a]	169 ± 0.97[b]	87 ± 0.50[d]
Magnesium	234 ± 1.35[b]	236.1 ± 1.36[a]	181.9 ± 1.05[c]	150.5 ± 0.87[d]
Phosphorus	222.1 ± 1.52[d]	267.4 ± 1.44[a]	263.1 ± 1.28[b]	249.3 ± 1.54[c]
Potassium	823.5 ± 5.20[c]	921.8 ± 4.47[a]	900.7 ± 4.75[b]	774.0 ± 5.32[d]
Iron	10.18 ± 5.88[c]	10.68 ± 6.16[b]	9.93 ± 5.73[d]	11.69 ± 6.75[a]
Sodium	6.21 ± 3.58[c]	6.74 ± 3.89[a]	4.91 ± 2.83[d]	6.32 ± 3.65[b]

Values are means ± standard deviations of three measures (n = 3). The same letter subscripted in the same line indicates that there is no significant difference between samples for the parameter concerned ($p<0.05$).
Fgbg: flour from large size white beans; **Fgrg:** flour from large size red beans; **Fgrp:** flour from small size red beans; **Fgbp:** flour from small size white beans.

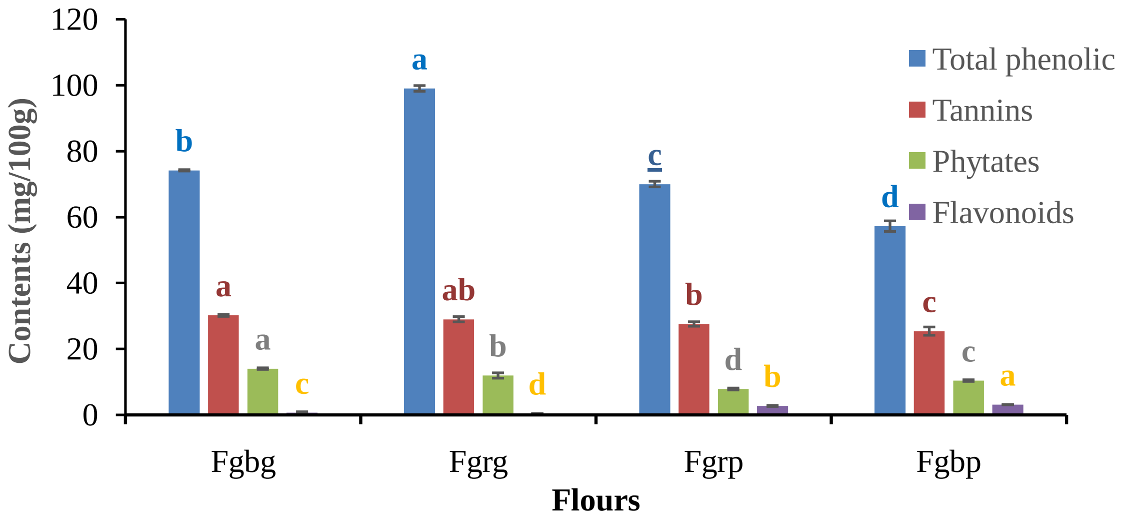
3.4. Amino acid Profile

The amino acid contents in different flours are presented in Table 3. The most highly concentrated of essential amino acids in flours were threonine, methionine, lysine, and valine. The results showed high content of threonine, methionine and lysine in the flours from red beans: (Fgrp) ≈ 26.09 ± 0.02 mg / 100g; 40.15 ± 0.03 mg / 100g and 12.34 ± 0.03 mg / 100g; (Fgrg) ≈ 25.45 ± 0.01 mg / 100g; 40.15 ± 0.02 mg / 100g and 10.03 ± 0.03 mg / 100g respectively compared to flours from white beans. In addition, Valine was high contents in flours from large size beans: (Fgbg) ≈ 16.07 ± 0.02 mg / 100g and (Fgrg) ≈ 07.70 ± 0.03 mg / 100g. For the other amino acids, their contents have been weakly represented. The results also showed that the red varieties of cowpea flours (Fgrg and Fgrp) were the high content of total amino acids 98.45±0.02 mg / 100g and 97.61±0.03 mg / 100g compared to those of white varieties (Fgbg) and (Fgbp) 83.26±0.02 mg / 100g and 79.17 ± 0.01 mg / 100g.

Table 3. Amino acid composition

Amino Acids (mg/100g)	Flours			
	Fgbg	Fgrg	Fgrp	Fgbp
Hist	4.25±0.01[b]	3.39±0.02[d]	5.81±0.02[a]	4.13±0.01[c]
Tryp	1.07±0.02[d]	5.14±0.01[c]	6.93±0.02[a]	5.96±0.03[b]
Thréo	23.85±0.03[b]	25.45±0.01[b]	26.09±0.02[a]	21.19±0.01[d]
Tyr	4.89±0.02[a]	4.20±0.03[b]	0.12±0.01[c]	0.04±0.02[d]
Val	16.07±0.02[a]	7.70±0.03[b]	6.17±0.02[d]	6.92±0.01[c]
Meth	25.32±0.01[c]	40.15±0.02[a]	40.15±0.02[a]	32.81±0.03[b]
Isol	0.73±0.02[d]	2.39±0.02[a]	2.00±0.03[b]	1.74±0.01[c]
Lys	7.08±0.01[c]	10.03±0.03[b]	12.34±0.03[a]	6.38±0.02[d]
Aa totaux	83.26±0.02[d]	98.45±0.02[a]	97.61±0.03[b]	79.17±0.01[c]

Values are means ± standard deviations of three measures (n = 3). The same letter subscripted in the same line indicates that there is no significant difference between samples for the parameter concerned ($p<0.05$).
Fgbg: flour from large size white beans; **Fgrg:** flour from large size red beans; **Fgrp:** flour from small size red beans; **Fgbp:** flour from small size white beans. **Hist:** Histidine**, Tryp:** Tryptophane**, Thréo:** Threonine**, Tyr:** Tyrosine**, Val:** Valine**, Meth:** Methionine**, Iso:** Isoleucine**, Lys :** Lysine**, Aa totaux:** Amino Acids totaux.



Values are means ± standard deviations of three measures (n = 3). The same letter subscripted in the same histogram indicates that there is no significant difference between samples for the parameter concerned ($p<0.05$). **Fgbg:** flour from large size white beans; **Fgrg:** flour from large size red beans; **Fgrp:** flour from small size red beans; **Fgbp:** flour from small size white beans.

Figure 1. Total polyphenols, tannins, phytates and flavonoids content of flours

3.5. Antinutrient and Antioxidant Factor Content

Total phenolic compounds, tannins, phytates and flavonoids are showed in the Figure 1. Statistical analyzes showed a significant difference (p≤0.05%) of polyphenols and phytates content in the different flours. The flours from large size beans (Fgbg and Fgrg) were higher total polyphenols and phytate content compared to those of small size (Fgbp and Fgrp). On the other hand, flours from small size cowpea grains (Fgbp and Fgrp) were higher in flavonoids compared to flours from large size (Fgbp and Fgrp). As for as tannins, the results showed a lower content in the flours from white small size grains (Fgbp) ≈ 25.40 ± 1.25 mg / 100g.

3.6. Functional Properties of Flour

Table 4 shows the Water Absorption Capacity (WAC), Water Solubility Index (WSI), Sunflower Oil Absorption Capacity (OACS) and Dinor Oil Absorption Capacity (OACD).

The results showed that the flours from red beans (Fgrg) and (Fgrp) were higher water absorption capacity contents respectively 360.88 ± 36.10% and 426.03 ± 31.16% compared to those from white beans. The same trends were observed for the water solubility index (WSI) with respective values 74.89 ± 21.44% and 53.18 ± 4.18%. On the other hand, the results did not show a significant difference between Sunflower Oil and Dinor Oil absorption capacity whatever the morphology characteristic of cowpea grains. However, the Dinor Oil absorption capacity (OACD) of cowpea flours were higher than that of Sunflower Oil absorption capacity (OACS).

3.7. Nutritional Profile of Flours

Figure 2 presents the SAIN and LIM scores of the flours from cowpea grains. The SAIN scores of Fgbg, Fgrg, Fgrp and Fgbp flours were respectively 12.40; 12.4; 11.51 and 11.95 and their LIM scores were respectively 2.73; 2.85; 3.64 and 2.78. These flours have a good nutritional profile because their SAIN were higher than 5 and their LIM were lower than 7.5. The different SAIN and LIM scores obtained were showed that all the cowpea flours studied belong to Group 1 foods. This group contains foods recommended for health.

Table 4. Functional properties of flour from cowpea grains

Fonctional properties (%)	Flours			
	Fgbg	Fgrg	Fgrp	Fgbp
WAC	300.55 ± 5.36^{c}	360.88 ± 36.10^{b}	426.03 ± 31.16^{a}	281.82 ± 22.52^{c}
WSI	34.60 ± 1.70^{b}	74.89 ± 21.44^{a}	53.18 ± 4.18^{b}	35.13 ± 1.06^{b}
OACS	102.13 ± 9.43^{a}	99.93 ± 24.34^{a}	94.23 ± 1.10^{a}	107.23 ± 4.23^{a}
OACD	111.70 ± 0.83^{a}	107.80 ± 6.16^{a}	106.27 ± 8.48^{a}	106.43 ± 3.18^{a}

Values are means ± standard deviations of three measures (n = 3). The same letter subscripted in the same line indicates that there is no significant difference between samples for the parameter concerned (p<0.05).
Fgbg: flour from large size white beans; **Fgrg:** flour from large size red beans; **Fgrp:** flour from small size red beans; **Fgbp:** flour from small size white beans. **WAC**: Water absorption capacity; **WSI**: Water solubility index; **OACS**: Sunflower oil absorption capacity; **OACD**: Dinor oil absorption capacity.

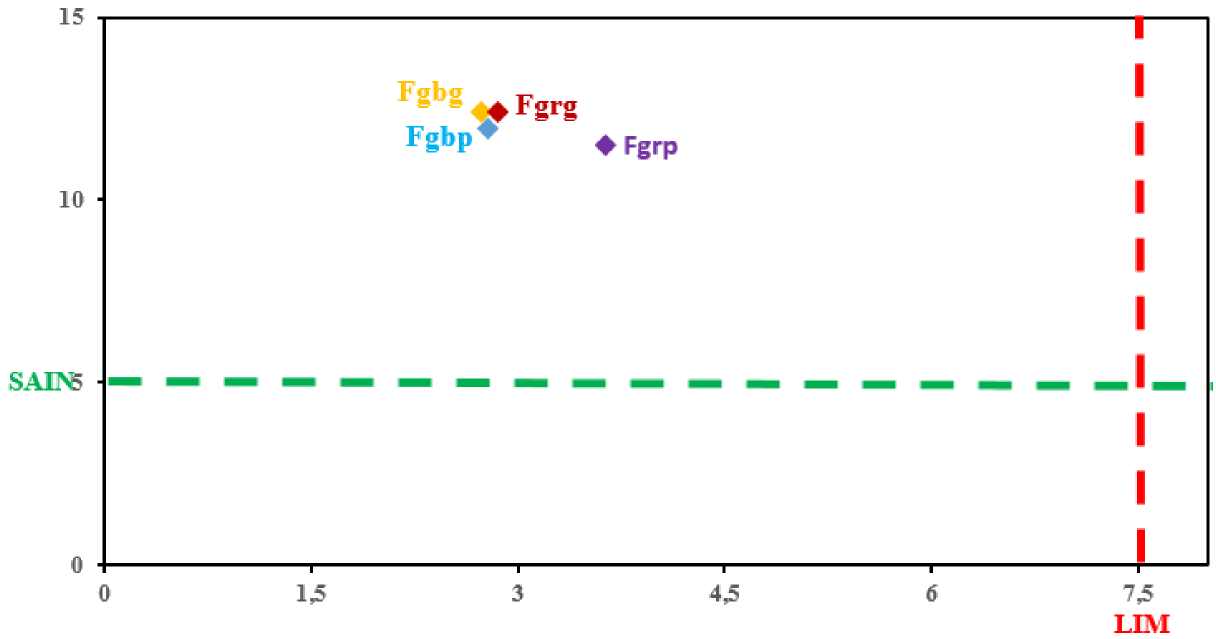


Figure 2. SAIN and LIM scores of cowpea flours

4. Discussion

The aims of this study was to evaluate the influence of morphological variability on the nutritional and technological characteristics of flours from cowpea grains. The results showed significant difference ($p < 0.05$) between flours for each parameter. The proportions of dry matter in all flours was greater than 85%. The high dry matter content could be explained by low moisture content. This low moisture content could be explained by the fact that the raw materials used for the production of these flours were from dried crops. This characteristic indicates that the resulted flours could be stored safely for long time without risk of microbial growth. In food, proteins are used to build, to repair muscles, tissues and to support the immune system. Consumption of foods rich in protein is involved in cell growth in children and, in the maintenance and regeneration of cells in adults. Large size of red varieties were higher protein contents compared to other varieties. These results were different from those of [32] who showed that the white varieties contains higher protein contents than those of red varieties. This difference of protein content between the two results could be explained by the different varieties and also the methods of analysis used. The protein contents obtained in this result were also higher than those of cereals which varies from 7 to 12% [33,34]. Due to the high protein content, red cowpea from large and small size could be used to replace animal protein in certain region and during the lean season in the diet. Also, adding red varieties cowpea to cereals could be contributes strongly to increase protein content in the final flour.

Regarding the amino acid profile, results showed that the high contents in the flours from red varieties were in agreement with those of [35]. In view of these results, the flours obtained from red varieties with high proteins content and high amino acids content could be used in food formulation of flours from cereals. The low fat content obtained in these results could be explained by the fact that dry legumes were low in fat. These results were similar to those obtained by [36,37] on other varieties of cowpea. Total carbohydrates content in this result were higher than 60%. Similar results were found by [38] in cowpea flour. Carbohydrates are essential compounds for all living organisms and they represent the most abundant macromolecules. In addition, 40 to 50% of the calories provided by human food come from carbohydrates [39]. The high protein and high carbohydrate content in red and white cowpea flours result in high-energy value (> 350 kcal / 100g). Due to the high-energy value, cowpea could be recommended in children and athletes diets.

From a dietary point of view, dietary fibers have several health benefits including fecal bolus, decreased cholesterol, plasma LDL (low density lipoprotein) level, blood glucose and postprandial insulinemia [40]. The fiber content of the flours whatever the color and the size were higher than those obtained by [36] on seven species of Vigna. The difference between these results may be due to the techniques of fiber determination and also by the different varieties of cowpea used.

The results showed that the different cowpea flours studied were the potential sources of minerals. Minerals are involved in several metabolic reactions within the body as cofactors [1]. The high potassium contents obtained in flours of red beans were in agreement with those obtained by [41]. In addition to potassium, the results showed that phosphorus, calcium and magnesium were the abundant minerals in the red varieties of cowpea studied. The differences of mineral content could be explained by the differences between the white and red varieties used. Phosphorus plays an essential role in the metabolism of proteins, fats and carbohydrates. Combined with calcium, phosphorus participates in the production of the bone structure [42]. As for as sodium, it plays an important role in the water balance of body. The sodium contents of the different varieties of cowpea used in this study were lower than those reported by [41] on various varieties of cowpea with values varies between (70.54 mg / 100g and 75.17 mg / 100g). This difference could be explained by the different varieties of cowpeas used, but also by the different methods of dosage.

The high levels of phenolic compounds of flours from large size beans were similar to those of [43,44]. These authors showed that the polyphenol level was higher in red beans varieties compared to white beans varieties.

Water absorption capacity (WAC) indicates the extent of starch gelatinization, On the other hand, Water solubility index (WSI) reflects the extent of starch degradation. Functional properties express the intrinsic physicochemical characteristics of food and affect its behavior during and after industrial processing. [45] showed that biochemical constituents such as protein, starch and dietary fiber influence the functional properties of food. The high levels of water absorption capacity and water solubilization index in flours from red grains (large and small size) could be explained by the interaction of the proteins contained in these flours with water. In addition, the hydration properties of these flours were showed that the flours could be used in baking. Water absorption capacity is an important property in flours for pastries. It allows addition of a lot of water to the paste while improving handling. The ability of legume to retain oil or fat is an important characteristic in the foods formulation. This characteristic allow to retain flavor and improve mouthfeel [45]. In addition, [46] showed that the oil absorption capacity was related to the nature and content of proteins, fibers and starch. Results showed that the absorption rate was higher with Dinor oil compared to sunflower oil whatever the flours studied. These results could be explained by the affinity or the specificity of Dinor oil, for the position of fatty acids on glycerol. Only 11% of palmitic acid was in position 2, a central position allowing maximum absorption without hydrolysis by lipases. In Côte d'Ivoire households, beans are eaten boiled in the presence of oil. The fact that Dinor oil costs less than sunflower oil, could encourage the consumption of cowpea in poor households and could help fight malnutrition.

As far as the nutritional profile, results showed that cowpea grains have a good nutritional profile because their have a high score SAIN higher than 5 and a low score LIM lower than 7.5. These score SAIN and LIM have classified cowpea in the group 1 food. This group contains foods recommended for health. The use of the SAIN and LIM system help to choose the best food for children and also help to reduce malnutrition. These results were in accordance with those obtained by [47]. These authors demonstrated that beans and peas have LIM scores below 7.5 and SAIN scores above 5. Beans and peas belong to the group of foods recommended for health. These results also corroborate with those obtained by [48] which showed that beans and peas are low in calories, rich in minerals and protein.

5. Conclusion

The objective of this work was to evaluate the influence of morphological variability on the nutritional and technological characteristics of flours from cowpea grains. This study showed that red varieties beans (small and large size) were good source of protein, polyphenolics and total amino acids. Also, the lage varieties cowpea red and white were good source of fiber, were high content of dry matter, therefore more resistant to microorganisms. On the other hand, large size of white cowpea beans were good source of minerals. The nutritional profile by SAIN> 5 and LIM <7.5 scores determination of cowpea flours showed that cowpea belong to the group 1 foods. This group contains foods healthy for consumption. The red and white cowpea could be recommended for the health and growth of children.

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Statement of Competing Interests

The authors have no competing interest in relation to their work.

List of Abbreviations

RNI: Recommended nutritional intake
SAIN: favorable aspects of the food
LIM: adverse aspects of the food
h: hour
DM: Dry matter.

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