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(RESEARCH ARTICLE)

Physical parameters and physico-chemical properties of two wild beans (*Phaseolus lunatus*) consumed in Côte d'Ivoire

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Abstract

In Côte d'Ivoire, many varieties of wild beans are frequently consumed. This study was conducted to know the physical parameters (length, width, thickness and weight) and some physicochemical properties of two varieties (white and red) of beans (*Phaseolus lunatus*). The lengths varied from 11.2±0.2 to 9.6±1.6 mm, widths from 7.9±0.6 to 9.6±1.6, thickness from 4.5±0.3 to 5.0±0.6 and weight from 715±0.03 to 931±0.07g. The capacities and hydration index varied respectively from 0.29±0.00 to 0.40±0.01 g/seed, from 0.40±0.01 to 0.66±0.01. The capacities and solubility index varied respectively from 0.28±0.01 to 0.45±0.02 ml/seed, from 0.65±0.4 to 0.875±0.66. The bean densities are 1.27±0.01 (white) and 1.32±0.01 (Red). Cooking times of bean seeds ranged from 45±2 (White) to 48±2 min (Red). Major physicochemical properties of bean flours are carbohydrates (54.89±0.54-63.03±0.9 mg/100g), protein (23.90±0.43-24.10±0.71 mg/100 g) and fibers (5.35±0.45-5.45±0.45 mg/100 g).The majority minerals in bean flours are potassium (1444.7±4.8-1206.7±2.9 mg/100 g), phosphorus (412±27- 451.91±14.6 mg/100 g) and calcium (268±0.12-297- 84±2.4 mg/100 g). The Ca/P and Na/K ratios of bean varieties flours are less than 1.

Keywords: Bean; Physical parameters; *Phaseolus lunatus*; Physico-chemical; Variety

1. Introduction

Lima bean (*Phaseolus lunatus* L.) is one of the five cultivated Phaseolus bean species, which originated in the Americas [1,2] and have been grown in the New World Tropics for up to ten thousand years [3]. *Phaseolus lunatus* belongs to the family Leguminosae, commonly known as lima bean is one of the important leguminous crops in the genus phaseolus noted for its nutritional and medicinal properties. They are a type of legume native to South American [4].

Although lima beans (*P. lunatus*) are less widely cultivated, they are a very important alternative source of income and food for local populations in regions such a northeastern Brazil [5]. Lima bean is cultivated primarily for its immature and dry seeds, which in tropical Africa are usually eaten boiled, fried in oil or baked. Beans are an important food crop both from the economic and nutritional points of view, and are cultivated and consumed worldwide [6]. As a result, dry beans are used throughout the world representing 50 % of the grain legumes consumed as a human food source. Bean forms a good source of income for farm families [7]. The varietal differences exist insize (small and large) and colour, usually ranging from green to creamy white and a phenomenal starchy flavor [8]. Lima bean like all other legumes are food resources that offer various optimum nutritional and/ or health benefits [9].

Legumes are all plants of the pea and beans family (Leguminoceae) which comprises the Caesalpinacea (Senna family), Mimosaceae (Locust bean) and Pappilionaceae [10]. They are of economic importance as cheap sources of protein, energy and other nutrients in the diets in most developing countries of the world. Legumes have been categorized either

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as major or minor based on their utilization. The major legumes include soybean, groundnut, cowpea, African locust bean while the usually regarded as miscellaneous, neglected or underutilized include Bambara groundnut, lima beans, pigeon peas, etc [11]. They are a rich source of proteins, complex carbohydrates, dietary fibres and minerals, but they also contain biologically active phytochemicals that are important for human health [12]. The major legumes have received much research attention unlike the minor legumes.

In Côte d'Ivoire, various varieties of wild beans are consumed and their nutritional potential are often inexistent or unknown. The aim of this study is to characterize the parameters (physical and physicochemical) of two varieties (purple and white) of wild beans to better understand their biochemical composition.

2. Material and methods

2.1. Sample Collection

The purple and white varieties (figure 1) of wild beans (*Phaseolus lunatus*) used in this study were collected at Bouaké (Center, Côte d'Ivoire). In this region, some populations use the bean plants for other purposes (fencing of houses, embellishment ...). These two varieties of beans were identified at the floristic center of Felix Houphouët Boigny University (Abidjan, Côte d'Ivoire). At maturity, the beans were removed from all impurities and taken to the laboratory of Biochemistry and Food Technology of Nangui Abrogoua University (Abidjan, Côte d'Ivoire) for analyzes.

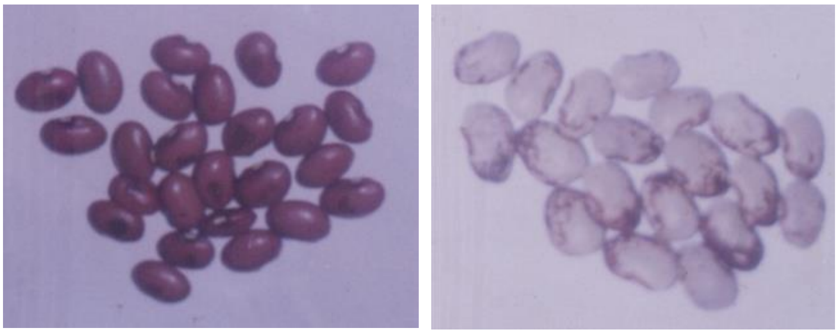

Figure 1 The two varieties (purple and white) of wild beans (*Phaseolus lunatus*)

2.2. Flours preparation

For each batch, a sufficient quantity (one kilogram) of bean seeds was taken, rinsed four times with deionized water, dried in a ventilated oven at 55 °C for 24 h, ground in an analytical flour mill and sieved with a sieve of 200 µm in diameter. The two bean (purple and white) flours obtained were stored in plastic containers and stored in the laboratory prior to use.

2.3. Physical measurements

The followings were the tools and equipment employed: Weights of the samples were determined by using a precision electronic balance reading to an accuracy of 0.01gm. To determine the average size of the seed, 100 seeds were randomly picked out of 120 seeds samples for Uyole-96 and their three principle dimensions (lengths, width, and thickness) were measured using a digital vernier caliper with an accuracy of 0.01 mm [13].

Hundred randomly selected seeds were used to measure length (L), breadth (B) and thickness (T), three principal dimensions which are in the three mutually perpendicular directions using A Vernier caliper reading 0.01 mm. 1000-seed weight was determined by counting one hundred seeds manually and weighing. The obtained values were then multiplied by a factor 10 to get 1000-seed weight [14]. Cooking time was determined according to the method [15].The seeds were weighed and cooked at 65 °C with 550 ml of distilled water.

2.4. Hydration Capacity and Hydration Index

Seeds (10 g) were soaked in 100 ml of distilled water in a measuring cylinder and covered with an aluminum foil. The seeds were left to soak for 24 h in room temperature (25 °C); drained and excess water was removed using a tissue paper. The weight of the swollen seeds was measured. Hydration capacity and hydration index were calculated [16].

$$\text{Hydration capacity} = \frac{\text{Weight after soaking} - \text{Weight before soaking}}{\text{Number of seed}}$$

$$\text{Hydration index} = \frac{\text{Hydration capacity of seed}}{\text{Weight of one seed}}$$

2.5. Swelling Capacity and Swelling Index

The volume of 5 g of seeds was predetermined using a graduated cylinder and they were subsequently soaked overnight in distilled water. The volume of the seeds after soaking was then measured. Swelling capacity and the swelling index were determined [16].

$$\text{Swelling capacity} = \frac{\text{Volume after soaking} - \text{Volume before soakingg}}{\text{Number of seed}}$$

$$\text{Swelling index} = \frac{\text{Swelling capacity of seed}}{\text{Number of seed}}$$

2.6. Density

Seeds (100 g) of the sample after accurately weighing, and transferred to a measuring cylinder, where 100 ml distilled water at 20 °C is added. Seed volume (ml/100 g seeds) was obtained after subtracting 100 ml from the total volume (ml). Volume increase measured immediately, so that swelling character not a problem. The density of bean seeds was calculated and recorded as g/ml [17].

2.7. Physicochemical analyzes

Proximate chemical composition analysis of the seed flour including moisture, total ash; crude protein (N × 6.25), fibers, fat and starch content were performed [18]. Total and reducing sugars contents were carried out [19, 20]. Total carbohydrate contents were evaluated [21]. Total carbohydrates excluding crude fiber were calculated by difference. Caloric energy was calculated according to Atwater general factor system [22]. The system uses a single factor for each of the energy-yielding substrates (protein, fat, carbohydrate) regardless of the food in which it is found. The energy values are 4.0 kcal/g for protein, 9.0 kcal/g for fat and 4.0 kcal/g for carbohydrates.

Minerals such as calcium (Ca), sodium (Na), potassium (K), iron (Fe) and phosphorus (P) were quantified by Atomic Absorption Spectrometer (Varian AA 20, Australia) and Spectrophotometer (UV/Visible Jasco V 530i) respectively, after digestion of samples [23,24]. The Ca/P and Na/K ratios was evaluated by calculation.

2.8. Statistical analysis

All analyses were performed in triplicates. Results were expressed by means of ± standard deviation. Statistical significance was established using Analysis of Variance (ANOVA) models to estimate the properties and parameters of bean flours. Means were separated according to Duncan's multiple range analysis ($p<0.05$), with the help of the software Statistica (StatSoft Inc, Tulsa USA Headquarters) [25].

3. Results and discussion

3.1. Physical parameters

Physic parameters of bean varieties (*Phaseolus lunatus*) flours are presented in table 1. Physical and mechanical properties are prerequisites in the design of suitable systems, machines, and structures for planting, harvesting, handling, processing, and storing of agro-products [26, 27]. This knowledge is important in the designing of machinery to harvest and in preparation of processing chain from grain to food. Knowledge of physical properties of agriculturally, nutritionally, and industrially valuated seed materials is imperative in designing the equipment for harvest, transport, storage, processing, cleaning, hulling, and milling [28, 29].

The length of bean seeds ranged from 11.2 mm (purple variety) to 15.2 mm (white varieties). Seed width ranged from 7.9 mm to 9.2 mm, and widths ranged from 4.5 mm (purple variety) to 5.0 mm (purple variety). There were significant differences in size (length and width) of seeds with the exception of thickness. Bean seeds (*Phaseolus lunatus*) are similar in size [30], [13] for different red bean cultivars. The thousand (1000) seed weight differed significantly (P<0.05) among all the two accessions with a range from 715.00 g for red bean to 931.00 g for white bean (table 1). The results are far higher than those reported [31] for three cowpea cultivars with 1000-seed weight in the range of 131.6–151.6 g. Additionally, [32] have reported 1000 seed mass for certain cowpea seeds in the range between 140.44 g and 192.81 g. The seed weight of bean (*Phaseolus lunatus*) variety could be a useful criterion for determining suitability for a particular end-use application. For example, varieties with large seeds would be preferred for canning, since this would mean less quantity of beans would be required to attain a high cooked bean weight. Furthermore, classification based on seed weight may be used to determine conformity to standards during quality control of raw materials. [33] identified five morphotypes of lima bean on the basis of hundred-seed weight, seed length, and seed width.

Table 1 Physic parameters of bean varieties (*Phaseolus lunatus*) flours

Physic parameters (mm)	Bean varieties	
	Purple	White
Length	11.2±0.2[a]	15.2±1.4[b]
Breadt	7.9±0.6[a]	9.6±1.6[b]
Tchickness	4.5±0.3[a]	5.0±0.6[b]
1000-seeds weight (g)	715±0.03[a]	931± 0.07[b]

Values are means of triplicate determinations ± standard deviation

3.2. Physico-chemical properties

Physical properties and cooking time of bean varieties (*Phaseolus lunatus*) flours are presented in table 2. Significant differences (P<0.05) were observed among the bean varieties for hydration and swelling capacities as well as hydration and swelling indices. White beans had the highest swelling index (0.875±0.06) whereas purple beans the lowest (0.652±0.043). High value of swelling index revealed high swelling ability of white seeds. The swelling ability of any seed depends upon its water retention capacity or hydration capacity. The hydration capacity of white bean seed was found to be 0.404±0.011 g/seed. The increase in the swelling capacity of white bean samples (0.451±0.022 mL/seed) could be due to their high protein contents [34]. Hydration capacity and hydration index of bean cultivars have been reported to vary between 0.31–0.59 g/seed and 0.78–1.25 respectively [35]. Hydration capacity determines the extent to which seeds absorb water on soaking. It depends upon chemical composition of seed coat and cotyledons [36]. The high swelling capacities of these beans will make them useful in the preparation of soups, puddings, and sauces.

Elevated hydration and swelling capacities of white bean shows their softness and high permeability. Also, a large hydration capacity leads to better cooking quality (less cooking time and texture). As cooking of white bean variety would require less fuel and energy, it should be preferred. The hydration index of red bean (0.402±0.002) was less than those of white bean varieties (0.657±0.001). These differences may be attributed to difference in size, seed coat thickness, and water absorption characteristics of seeds [37]. The seed density of purple bean seeds (1.317±0.012 g/mL) was higher than those of white bean (1.270±0.025 g/mL). The density of dry beans was higher than 1g/mL indicating that the seeds are heavier than water and hence sink. The values were statistically different (P<0.05). [38] analyzed some samples of common bean and found that mean value of seed density was around 1.25 g/mL. The results obtained for cooking properties of haricot bean (*Phaseolus lunatus*) are given in Table 3. Cooking time is one of the main considerations used for evaluating pulse cooking quality. Longer cooking times result in a loss of nutrients and could limit end-uses. Hence, consideration of cooking time is of paramount importance. White bean and purple bean varieties required the minimum and maximum cooking time of 45.00±2 and 48.00±2 min, respectively. As white bean varieties, had higher hydration and swelling capacities, he required less cooking time. The hardness of the cooked bean is defined, as the maximum force required for 75% deformation of seeds after cooking. The force required for seed deformation was less for white bean and this variety also had the smallest cooking time.

Table 2 Physical properties and cooking time of bean varieties (*Phaseolus lunatus*) flours

Physical properties	Bean varieties	
	Purple	White
Hydratation capacity (g/seed)	0.29±0.00[a]	0.40±0.01[b]
Hydratation index	0.40±0.01[a]	0.66±0.01[b]
Swelling capacity (mL/seed)	0.28±0.01[a]	0.45±0.02[b]
Swelling index	0.65±0.04[a]	0.87±0.06[b]
Density	1.32±0.01[a]	1.27±0.01[b]
Cooking times (min)	48±2[a]	45±2[b]

Values are means of triplicate determinations ± standard deviation

3.3. Proximate composition

The proximate composition of two varieties beans (*Phaseolus lunatus*) is presented in table 3. For the two varieties, significant differences ($P < 0.05$) were observed in some nutrient contents (moisture, carbohydrates, starch, total sugar, reducing sugar).

Moisture content of beans ranged from 10.33±0.02 to 19.8±0.01 mg/100g for purple and white varieties beans respectively. Moisture content estimates directly the water content and indirectly the dry matter content of the sample. It is also an index of storage stability of the flour. Flour with moisture content less than 14 % can resist microbial growth and thus has better storability [39, 40]. The results show that the moisture contents range was within those [41] for barley grains which was 7.34 to 21.58 mg/100g and for fennel seed (*Foeniculum vulgare*) which were between 7.78% to 21.67 mg/100g [42]. However, the moisture content is mainly dependent on drying and storage conditions, but not due to variety.

There was no significant difference between the protein content of both the samples (Table 3). Protein is an essential nutrient ranks second place after water in occupying most plentiful substance in our body. The results show that the two beans (purple and white) are rich source of protein as compared to red gram (22.3 mg/100g), Bengal gram (20 mg/100g) and green gram (24 mg/100g) which are commonly consumed in India [43]. The mean protein of two beans varieties content was higher to what has been reported in other studies elsewhere [44, 45, 46].

Fat content in the two samples was low (0.80±0.05 -0.81±0.01 mg/100g) and in agreement with other observations for lablab beans [47, 48] and other commonly consumed legume grains [49, 50, 51, 52].

The relatively high carbohydrates content and energy values of the beans seeds observed in this study are similar to those observed in other studies [53, 54, 55]. They are also within the range of the other most commonly consumed legume grains [56]. The highest carbohydrate content (63.03±0.9 mg/100g) was reported for red bean varieties and the lowest for white bean (54.89±0.54 mg/100g). Significant differences were found in carbohydrate content among the varieties. Comparable results for composition of bean have been reported [57]. The differences in composition of beans (*Phaseolus lunatus*) could be due to the genetic differences.

Total ash content in two varieties was between 4.37±0.19 (purple variety) and 4.14±0.72 mg/100g (red variety). These values are in agreement with those reported in other studies [58, 51]. However, they are higher in comparison to those [59]. The ash content is an indicator of the mineral content in the beans.

There was significant difference between the fibers content of the samples (Table 3). Authors have reported the crude fibers content of kidney beans as 4.2 per cent and 7.0 per cent respectively [43, 60]. These values are less than the crude fibers content (5.35-5.45 mg/100g) obtained in the present study. Higher crude fibers content (7.87 and 8.16 mg/100g) has been found in kidney beans as compared to lentil (0.7 mg/100g), green gram (4.1 mg/100g), soyabean (3.7 mg/100g) and cow pea (3.8 mg/100g) also make them suitable for their use in preventing certain degenerative diseases like diabetes, cancer and heart disease [43].

There was significant difference between the starch content of the samples (Table 3). The starch is the most important chemical component in the flours. Apart from its energy contribution, starch in most of the processed food systems is known to contribute to the texture, and as a result, to the organoleptic properties of food [9].

Energy is essential for rest, activity and growth. Carbohydrate, protein and fat are three components which provide energy [43]. The data presented in Table 2 indicated that the purple bean (355.01 Kcal/ 100 g) exhibited significantly higher value for physiological energy and the lowest physiological energy (308.39 Kcal/100g) has been observed in white beans. Authors have reported the energy value of kidney beans as 346 Kcal/100g and 327 Kcal/100g [43,61]. Researchers have reported that legumes could prevent or manage chronic health challenges such as diabetes, cardiovascular disease, cancer, obesity and contribute to overall health and wellness of human body [62].

Table 3 Proximate composition of two bean varieties (*Phaseolus lunatus*)

Composition (mg/100g)	Bean flours	
	Purple	**White**
Moisture	10.33±0.02^{a}	19.80±0.01^{b}
Protein	23.90±0.43^{a}	24.10±0.71^{a}
Fat	0.81±0.05^{a}	0.80±0.01^{a}
Carbohydrates	63.03±0.9^{a}	54.89±0.54^{b}
Starch	60.23 ± 0.7^{a}	53.51±0.5^{b}
Total sugar	2.8±0.02^{a}	1.36±0.04^{b}
Reducing sugar	0.23±0.02^{a}	0.64±0.04^{b}
Ash	4.37±0.19^{a}	4.14±0.72^{a}
Fibers	5.35±0.45^{a}	5.45±0.45^{a}
Energy (Kcal/100g)	355.01^{a}	323.16^{b}

Values are means of triplicate determinations ± standard deviation

3.4. Mineral composition

Mineral composition of bean varieties (*Phaseolus lunatus*) flours are presented in table 4.

Different mineral composition may be due to differences in genes, geographical origin and growing environment in terms of e.g. rainfall pattern, soil fertility and temperature [63]. Minerals are fundamentally metals and other inorganic compounds that are essential for human nutrition and maintenance of certain physicochemical processes which are necessary to life. They play a critical role in the formation of skeletal structure, serving as essential co-factors for a number of enzymes and used for the utilization of nutrients and enzymes responsible for digestion and absorption [64].

The major minerals in the studied varieties were potassium and phosphorus which agrees with the observation of [65] on the potassium predominance in agricultural products. Similar observations have been reported for gingerbread plum [66] and lima bean seed coat [67] but contrary to the report on mucuna beans [16]. The samples are high in phosphorus and calcium, the minerals which are necessary for teeth and bone development in children [68].

Variation was observed in the quantitative composition of mineral elements in agreement [67] as a result of genetic variation and soil conditions. Na/K ratio observed in this study is within the recommended level (≤ 1.0) [11] and very vital in the prevention and management of high blood pressure. Ca/P ratio is high (high calcium, low phosphorus intake) only little amount of calcium will be loss through the urine, increasing the calcium level in bones. The Ca/P (0.651 to 0.659) ratio in the present study which is above 0.5 is an indication that the varieties evaluated are potential minerals sources for bone formation [69].

Table 4 Mineral composition of bean varieties (*Phaseolus lunatus*) flours

Composition (mg/100g)	Bean varieties	
	Purple	White
Phosphorus	412±27[a]	451.91±14.6[b]
Calcium	268±0.12[a]	297.84±2.4[b]
Potassium	1444.7±4.8[a]	1206.7±2.9[b]
Sodium	8.01±0.32[a]	14.07±1.6[b]
Iron	15.22±0.32[a]	73.7±3.7[b]
Ca/P	0.65[a]	0.66[a]
Na/K	0.006[a]	0.012[b]

Values are means of triplicate determinations ± standard deviation

4. Conclusion

This study provided basic information on the composition and physical parameters of two wild bean varieties (*Phaseolus lunatus*). The white variety has the best characteristics (physical and physicochemical) and a reduced cooking time (45 min). Proteins, ash and fibers contents of both varieties present no significant difference ($p < 0.05$). The mineral content differs significantly from one variety to another and the most dominant are potassium, phosphorus and calcium. The research results can be used by investigators and food businesses to develop recipes for processed bean foods, including fortified products.

Compliance with ethical standards

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Disclosure of conflict of interest

Ekissi ESG, Yapi JC, Kouadio TM, Gouledji AA and Kouame PL are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as constituting a conflict of interest.

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