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Proximate Composition, Minerals Content and Functional Properties of Five Lima Bean Accessions

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Abstract In order to combat food insecurity in Ghana and Africa as a whole, efforts are being made by the Crops Research Institute, of the Council for Scientific and Industrial Research (CSIR), Ghana, to produce new bean varieties with improved characteristics such as high yield, disease resistance and high nutritional value. Some of the new lima bean (*Phaseolus lunatus*) accessions collected include: Koloenu white, Koloenu brown, Nsawam black and white, Ohwam Mampong and Koloenu small black and white. The objective of the present work was to evaluate the proximate composition, minerals content and functional properties of flour from these five lima bean accessions. The proximate and functional properties were determined using standard procedures whereas minerals content by atomic absorption spectrophotometry. The crude protein content was in the range of 20.69–23.08 %, crude fat, 0.59–1.14 %, crude fibre, 4.06–6.86 %, ash, 4.39–5.61%, moisture 9.19-11.83 %, carbohydrate 54.31-59.64 % and energy, 313.28-328.10 kcal/100 g. The mineral content was in the range of 2.45–172.77 mg/100g, for Iron and Phosphorus respectively. The functional properties of the flours: foaming capacity, solubility capacity, bulk density, swelling index, water absorption capacity, and emulsion capacity were in the range of 18.00-22.13%, 17.00-21.01%, 0.66 g/mL, 0.98-1.64, 0.88-1.41 g/g, and 49.63-59.99%, respectively. The results indicate that, lima beans are rich in protein and have appreciable functional properties that could be exploited in food formulations such as koose, sauces and stews. The lima bean flours could also be used to fortify conventional flours which are low in protein and fiber.

Keywords: *proximate composition, lima bean accessions, minerals, functional properties*

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1. Introduction

Lima bean, *Phaseolus lunatus* belongs to the family leguminosae and is mostly cultivated in South America [1]. Lima beans are sometimes referred to as: haba beans, sugar beans, butter beans, Guffin beans, civet beans, Hibbert beans, Pallar beans, Sieva beans, Madagascar beans, and Burma beans. The varietal differences exist in size (small and large) and colour, usually ranging from green to creamy white and a phenomenal starchy flavor [2].

Lima bean like all other legumes are food resources that offer various optimum nutritional and/ or health benefits [3]. The protein content of legume grains range from 17 to 40 g/100 g, much higher than that in cereals (7-11.8 g/100 g) and approximately equal to the protein content of meat 18-25 g/100 g [4]. In Ghana and other developing countries, legumes are the second largest sources of human food after cereals. Lima beans is the fourth important legume food in Ghana after cowpea, groundnut and bambara groundnut. The high protein content as well as the presence of the amino acid lysine makes them a suitable cheap source for fortification of cereal diets in most economies in transition [5]. Health problems such as hypertension, gall-stone formation which are related to animal protein consumption have raised great social and public health attention recently. Thus, plant protein of which legumes form a great majority has been found to play an important role in several favorable physiological responses, such as reducing heart and kidney diseases, lowering the sugar indices of diabetic patients, increasing in satiety, and reducing the occurrence of cancer [5,6]. The utilization and exploitation of a crop generally depends on the available knowledge on it. The dearth of information on Lima beans in lieu with their optimum nutritional and functional properties has made this potentially beneficial legume under-utilized. As with legumes, some undesirable constituents of lima beans include antinutrients (trypsin inhibitors, phytic acid, saponins, haematoglutinns and tannins) that interfere with absorption and utilization of important minerals such as calcium, iron, zinc and magnesium. Lectins presents in beans are polymeric proteins that bind to monosaccharide in glycoproteins of the cell membrane causing lesions in the intestinal mucosa and reduced nutrient absorption. Lima beans are also known to contain relative high amounts of cyanogenic glycosides (linamarin or phaseolunatin) and thus need to be treated prior to utilization. It is known that processing methods such as dehusking, soaking, germination, cooking and roasting inactivate the antinutrients and can be used to improve the nutritional quality of the beans [7,8].

The objective of the present work is to determine the proximate composition, minerals content and functional properties of flour from five lima bean accessions.

2. Materials and Methods

2.1. Collection and Preparation of Samples

Five lima beans (*Phaseolus lunatus*) accessions designated: koloenu small black and white, koloenu brown, koloenu white, Nsawam (cream and black) and ohwam mampong were collected from Crop Research Institute/(CSIR), Kumasi, Ghana. The bean samples were sun and oven dried to constant mass, milled to a particle size of 0.2mm using a hammer mill, packaged in a low density polyethylene bag (LDPE) and kept in a cool dry place pending analysis.

2.2. Proximate Analysis

Proximate analysis of the lima bean was carried out to determine crude protein, crude fibre, total ash, crude fibre, total carbohydrate, crude lipid and moisture content using the methods of AOAC (2000) [9]. Triplicate determinations were made whereby the average and standard deviations are reported.

2.3. Minerals Analysis

Samples were dry-ashed according to AOAC [9]. Aliquots were analyzed for mineral components of potassium, sodium and iron using atomic absorption spectrophotometer (Buck, 210 Model) while phosphorus was determined calorimetrically [9].

2.4. Functional Properties Measurement

2.4.1. Solubility Capacity

Water solubility capacity of the beans flours was determined by the method of Aoki et al., [10]. Flour samples (2.5 g each) were dispersed in 30 mL of distilled water, using a glass rod, and cooked at 90°C for 15 min in a water bath. The cooked paste was cooled to room temperature and transferred into tared centrifuge tubes, and then centrifuged at 3000g for 10min. The supernatant was decanted for determination of its solid content into a tared evaporating dish and the sediment was weighed. The weight of dry solids was recovered by evaporating the supernatant overnight at 110°C.

2.4.2. Emulsion Activity

Emulsifying properties were determined according to the method of Naczk et al., [11]. Flour samples (3.5 g each) were homogenized for 30s in 50 mL water in a homogenizer. Groundnut oil (25 mL) was added to each, and the mixture was homogenized again for 30 s. Then, another 25 mL of groundnut oil were added to each, and the mixture homogenized for 90 s. Each emulsion was divided evenly into two 50 mL centrifuge tubes and centrifuged at 1100g for 5 min.

2.4.3. Foaming Capacity

Foaming capacity was measured according to the methods described by Sathe and Salunkhe [12]. The flour sample` (0.5 g each) was blended for 30 min in distilled water (40 ml) at top speed in a blender. The blender was rinsed with 10 ml distilled water and then gently added to the graduated cylinder. Foam volume in the cylinder was recorded per sample after 30 min standing. Triplicate measurement was taken for each sample and mean values recorded.

2.4.4. Water Absorption Capacity

Water absorption of the beans flours were measured by the centrifugation method of Sosulski and Fleming [13]. The samples (3.0 g each) were dispersed in 25 mL of distilled water and placed in pre-weighed centrifuge tubes. The dispersions were stirred occasionally, held for 30 min, followed by centrifugation for 25 min at 3000g. The supernatant was decanted, excess moisture was removed by draining for 25 min at 50ºC and sample was reweighed.

2.4.5. Swelling Index

The method of Abbey and Ibeh [14] was employed four the determination of the swelling indices of the flour samples. One gram of the flour samples was weighed into 10 mL graduation measuring cylinder. Five milliliters of distilled water was carefully added and the volume occupied by the sample was recorded. The sample was allowed to stand undistributed in water for 1 h and the volume occupied after swelling was determined.

2.4.6. Bulk Density

Ten grams of each sample was weighed and transferred into a measuring cylinder and the volume occupied by the flour recorded. This determinations were done in three replicates and their mean and standard deviations were recorded

2.7. Statistical Analysis

Data were subjected to analysis of variance and means were compared with Duncan Multiple range test using SPSS (version 20, IBM SPSS Statistics, US).

3. Results and Discussion

3.1. Proximate Composition

The results of the proximate composition of the five lima beans accessions are displayed in Table 1. The crude protein ranged from 20.69 to 23.08% with Koloenu small black recording the lowest and Ohwam Mampong recording the highest protein content. These values are in conformity with values described in literature [15,16,17,18] but relatively lower than that reported by Moses *et al*., [19]. Variations in protein content can be attributed to different environmental conditions, genotype and analytical methods. In addition, protein content was sensitive to rainfall, light intensity, length of growing season, day duration, temperature and agronomic practices [20].

Table 1. Proximate compositions of lima beans accessions

Sample names	Moisture (%)	Protein (%)	Fat (%)	Fiber (%)	Ash (%)	Carbohydrate (%)	Energy (kcal/100g)
Koloenu White	9.81 ±0.01[a]	21.22 ±0.07[a]	0.77 ±0.01[a]	4.17 ±0.01[a]	4.39 ±0.01[a]	59.64 ±0.28[a]	326.56 ±0.00[a]
Koloenu Brown	9.19 ±0.01[b]	21.76 ±0.00[a]	0.81 ±0.01[b]	6.86 ±0.15[b]	4.46 ±0.03[a]	56.93±0.14[b]	317.98 ±0.54[b]
Nsawam Black And White	11.83 ±0.07[c]	22.96 ±0.02[b]	1.14 ±0.23[c]	4.16 ±0.01[a]	5.61 ±0.06[b]	54.31 ±0.01[c]	314.96 ±0.11[c]
Ohwam Mampong	9.57±0.02[d]	23.08 ±0.03[c]	0.71 ±0.01[d]	4.06 ±0.02[c]	4.41 ±0.02[a]	58.24 ±0.05[d]	328.10 ±0.37[d]
Koloenu Small Black & White	11.26 ±0.01[e]	20.69 ±0.00[d]	0.59 ±0.01[e]	4.81 ±0.04[d]	5.61 ±0.02[b]	57.05 ±0.04[b]	313.28 ±0.17[e]

Values are the means of triplicate determinations ± standard deviation. Mean values in the same column with different superscript latters are significantly different (p <0.05).

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 [21]. The moisture contents of the five lima bean accessions ranged from 9.19% to 11.83% with 'Koloenu brown' recoding the lowest moisture content while 'Nsawam black and white' recorded the highest moisture content. Results obtained in the current study agrees with the recommended moisture contents for flour [22] but differ from findings previously reported [19,23].

Crude fiber refers to the indigestible plant material. It lowers blood cholesterol level in humans, prevent cancer, reduces the risk of developing diabetes, hypertension, and hypercholesterolemia [24]. The fiber content recorded in the current study ranged between 4.06% and 6.86% with 'Ohwam Mampong' recording the lowest values while 'Koloenu brown' recorded the highest value (Table 1). These findings are in line with values reported previously [19,23,25,26,27,28]. Current results for the five bean accessions are also in agreement with findings of Fasoyiro *et al.*, [26] who recorded values of 1.98% to 7.20% fiber for different legumes. There was generally a significant difference between the five samples at 95% confidence level (p<0.05). However, these values are different from findings in earlier investigations in the same species [25,26].

Results for ash content demonstrated significantly highest amounts in ''Koloenu small black and white' (5.61±0.02%) and 'Nsawam black and white' (5.61±0.06%) but lowest in 'Koloenu white' (4.39±0.01). These values are similar to those previously reported by Moses *et al.*, [19] and Fasoyiro *et al.*, [26] whereas others differ [23,27]. The relatively higher ash content of the 'Nsawam black and white' variety (5.61±0.05) generally indicates higher concentration of minerals than the other varieties. There was no significant difference (p<0.05) between 'Koloenu white', Koloenu small black and white' and 'Koloenu brown' but these differed significantly from the other two cultivars. 'Ohwam Mampong' and 'Nsawam black and white' were not significantly different (p>0.05).

The energy contents were found to be in the range of 313 to 328kcal/100g, these values are slightly different from those reported in literature [19,26,27]. The differences in the energy contents are result of the differences in protein content, carbohydrate, and fat contents.

3.2. Functional Properties

The functional properties evaluated in the present study included water absorption capacity, emulsifying activity, foaming capacity, bulk density and swelling power (Table 2).

The water absorption capacity (WAC) of flour plays an important role in food preparation due to its influence on other functional and sensory properties [29]. The WAC of flour sample in the current study ranged from 0.89 to 1.2 (g/g) where the highest value was obtained from 'Koloenu small black and white' cultivar and the lowest value was determined from 'Ohwam Mampong' cultivar bean flour (Table 2). Water absorption ccapacity represents the ability of a product to associate with water under conditions where water is limiting. Flours with high water absorption have more hydrophilic constituents, such as polysaccharides. The inherent proteins in the 'Koloenu small black and white' cultivar variety flour may also have played some role in their higher WAC. Interestingly these values are in agreement with those reported by Ekpo and Ugbenyen, [32] and Moses *et al.*, [19] but higher than that reported by Kaur and Sigh, [33]. The water absorption capacity of legume flours greatly influences the texture of food made from cereal- legume composite flours. These values differed significantly (p<0.05) except for 'Koloenu brown' and Nsawam black and white.

Table 2. Functional properties of lima beans

Sample names	Foaming capacity (%)	Solubility capacity (%)	Bulk density (g/mL)	Swelling index (v/v)	Water adsorption (g/g)	Emulsion capacity (v/v) (%)
Koloenu White	20.00 ±0.33[a]	21.01 ±0.04[a]	0.79 ±0.00[a]	1.64 ±0.02[a]	1.22 ±0.021[a]	59.99 ±0.02[a]
Koloenu Brown	19.99 ±0.01[a]	19.76 ±0.13[b]	0.79 ±0.00[a]	1.22 ±0.02[b]	1.01 ±0.01[b]	53.76 ±0.01[b]
Nsawam Black And White	22.13 ±0.15[b]	17.00 ±0.10[c]	0.83 ±0.00[b]	1.02 ±0.01[c]	1.00 ±0.01[b]	53.42 ±0.02[c]
Ohwam Mampong	18.67 ±0.29[c]	20.07 ±0.03[b]	0.66 ±0.01[c]	0.98 ±0.01[d]	0.88 ±0.01[c]	49.63 ±0.03[d]
Koloenu Small Black And White	19.21 ±0.15[d]	19.31 ±0.33[d]	0.68 ±0.02[c]	1.53 ±0.01[e]	1.41 ±0.014[d]	45.75 ±0.01[e]

Values are the means of triplicate determinations ± standard deviation. Mean values in the same column with different superscript latters are significantly different (p <0.05).

Emulsifying activity (EA) reflects the capacity of flour to aid in the formation of an emulsion and is related to the protein's ability to absorb to the interfacial area of oil and water in an emulsion. Flours from the various lima beans accession differed significantly in their abilities to emulsify groundnut oil (p<0.05). The emulsion activity of the flours ranged from 45.75% to 60% which are in line with those reported by Ekpo and Ugbenyen, [32] but differ from findings of Moses *et al.*, [19]. Flours from ‘Koloenu white’ cultivar showed significantly higher emulsion activity (60%) than did in other four cultivar flour samples. The difference in total protein composition (soluble plus insoluble) in the flour sample, as well as components other than proteins (possibly carbohydrates), may contribute substantially to the emulsification properties of these flours [29].

Foaming capacity generally depends on the interfacial film formed by proteins, which maintains the air bubbles in suspension and slows down the rate of coalescence. Foaming properties are dependent on the proteins and some other components, such as carbohydrates, that are present in the flours [29,30,31]. The foaming capacities of different legume flours ranged from 19.21% to 22.13% (Table 2) with ‘Nsawam black and white’ cultivar recording the highest value and ‘Koloenu small black and white’ recording the lowest foam activity. The good foam activity of the ‘Nsawam black and white’ cultivar flours suggests that the native proteins that are soluble in the continuous phase (water) are very surface- active in flours. Furthermore, legumes generally have a high amount of suface active saponins, which are also water soluble and may therfore influence the foaming capacity [20,29,32]. Ekpo and Ugbenyen, [32] recorded 14.36% to 20.30% of foam capacity for different lima beans flour which are similar to the present findings. These values are different from those reported by Moses *et al.*, [19] which might be as a result of different methods used for the analysis. Diversity of foaming capacities among the cultivars was also observed at 95% confidence level but significantly the same for Koloenu white and Koloenu brown ($p<0.05$) which might be caused by differences in the state of protein denaturation or composition of soluble proteins in the flour samples.

Solubility index determines its use in foods. The water solubility of the flour indicates the solubility of molecules; these differed significantly ($P<0.05$) among the flours except for ‘Koloenu brown’ and ‘Ohwam Mampong’ where there exist no significant difference between them. They varied from 17 to 21.01% where the highest value was obtained from ‘Koloenu white’ cultivar flour and the lowest value was determined from ‘Nsawam black and white’ cultivar flour. Difference in values may be as a result of the formation of amylose-lipid and protein-starch complexes in the process of heating [35].

Bulk density depends on the particle size of the samples. It is a measure of heaviness of a flour sample. It is important for determining packaging requirements; material handling and application in wet processing in the food industry. The bulk density for beans accessions flours varied from 0.66 g/mL to 0.83 g/mL, where the highest and the lowest values were obtained from Nsawam Black and White flour and black bean flour, respectively. Significant differences were observed among the bulk densities of the flours from different bean accessions in (Table 2). However, there was no significant difference ($p>0.05$) between Koloenu white and Koloenu brown, also there was no significant difference ($p>0.05$) between Ohwam Mampong and Koloenu small black and white in terms of their bulk density values. These values are in line with those reported by Moses *et al.*, [19]. The higher bulk density of Nsawam cultivar flour suggests that it is denser than the other cultivar flours. Also, Kaur and Singh [33] reported that the bulk densities of different legume varieties ranged from 0.536 to 0.971 g/mL, which are comparable to the results in this study. The bulk densities of these flours could be exploited in weanling food formulations, reducing the bulk density of the flour is probably helpful to the formulation of weanling foods [36].

Swelling power is a measure of hydration capacity, because the determination is a weight measure of swollen starch granules and their occluded water. Food eating quality is often connected with retention of water in the swollen starch granules [34,37].Values of the swelling power of the five lima bean accessions ranged from 0.98 to 1.64%. There were significant differences ($p<0.05$) among the five flour samples. However, ‘Koloenu white’ cultivar flour exhibited highest swelling power compared to the other samples with ‘Ohwam Mampong’ recording the lowest swelling power. These values are in line with those reported by Moses *et al.*, [19]. The extent of swelling of the flour depends on the temperature, availability of water, species of starch, extent of starch damage due to thermal and mechanical processes and other carbohydrates (such as pectins, hemicelluloses and cellulose) and protein [36,37,38].

3.3. Minerals

The Lima bean accessions were observed to contain fairly good amounts of minerals such as potassium, sodium, phosphorous and iron (Table 3).

Table 3. Mineral compositions of five Lima bean accessions (mg100 g $^{-1}$)

Sample name	K	Na	Fe	P
Koloenu White	50.04±0.02^{a}	20.01±0.01^{a}	2.67±0.01^{a}	170.96±0.03^{a}
Koloenu Brown	51.99±0.01^{b}	21.33±0.01^{b}	2.45±0.02^{b}	167.09±0.00^{b}
Nsawam Black And White	50.04±0.01^{a}	20.52±0.03^{c}	2.45±0.02^{b}	172.77±0.021^{c}
Ohwam Mampong	50.66±0.014^{c}	19.99±0.02^{d}	2.55±0.02^{c}	154.98±0.02^{d}
Koloenu Small Black And White	52.08±0.02^{d}	20.04±0.01^{d}	2.52±0.01^{c}	164.97±0.02^{e}

Values are the means of triplicate determinations ± standard deviation. Mean values in the same column with different superscript latters are significantly different ($p<0.05$).

Sodium in the form of sodium chloride is ingested directly though food and many food materials contain this salt. Sodium helps our body retaining the body’s water and pH. It enables our cell walls to draw in nutrients [39]. The values recorded for the sodium content ranged from 19.99 to 21.33 mg100g^{-1} with Koloenu brown recording the highest sodium content and Ohwam Mampong recording the lowest value. There was generally significant difference ($p<0.05$) between all the cultivars except for Ohwam Mampong and Koloenu small black and white where there exist no significant difference between them ($p>0.05$). These values recorded are slightly lower than those report in previous literature such as those of [26,27,28] for both species and other legumes. These amounts of Na in the legumes are in the tolerable level for human health [39]. Apata and Ologhobo [40] reported the association of high sodium content with hypertension. Higher sodium intake leads to the retention of more water including water in the blood vessels. This raises the blood pressure. If it raises the blood pressure too high, this can cause health problems such as hypertension.

The iron content ranged from 2.45 to 2.67mg$100g^{-1}$. Present findings regarding iron content are lower than the recommended daily intake and hence there is a need to complement these flours with flours of higher iron contents. These present findings are in accordance with those reported by Kathirvel and Kumudha, [28] but slightly different from those reported by Ikechukwu and Madu [27] and Fasoyiro *et al.*, [26]. These values are in line with values recorded for broad spectrum of legumes by Fasoyiro *et al.*, [26] who recorded values of 0.002% to 0.008% of iron content. These values differed significantly ($p<0.05$) except for Koloenu brown and Nsawam black and white where there exist no significant difference between them.

Phosphorous was the predominant mineral in the bean accessions, with values ranging from 154.98 to 172.77 mg $100g^{-1}$. Nsawam black and white recorded the highest value and Ohwam Mampong recording the lowest content. There was generally significant difference ($p<0.05$) between the five cultivars which might be as a result of genetic origin, geographical source and levels of soil fertility of the five Lima bean accessions. These values are in line with previous literature such as those of [26,28] for the same species and broad spectrum of legumes respectively. Phosphorous helps build and protect bones and teeth, as part of DNA and RNA, helps convert food into energy, the recommended daily allowance for both men and woman is 700mg, which means that one has to take in much of these flours in order to achieve this value for the proper functioning of the body hence there is the need to complement these flours with phosphorous rich sources.

The potassium content of the five lima bean accessions were found to be in the range of 50.04 to 52.08 mg $100g^{-1}$ with Koloenu small black and white recording the highest content and Koloenu white. There was no significant difference between Koloenu white and Nsawam black and white but differed significantly ($p<0.05$) between the other three cultivars. These values are lower than those reported in previous literature such as Kathirvel and Kumudha, [28] and Ikechukwu and Madu, [27] for the same species. Also these values are totally different from those reported for other legumes [26]. Potassium is nutritionally important in the maintenance of cellular water balance, pH regulation in the body and it is also associated with protein and carbohydrate metabolism [41]. A diet rich in potassium seems to lower blood pressure, getting enough potassium from diet may benefit bones.

4. Conclusions

Lima beans are rich in protein and have appreciable functional properties that could be exploited in food formulations such as koose, sauces and stews. The lima bean flours could also be used to fortify conventional flours which are low in protein and fiber. Therefore, increased efforts should be made to encourage the cultivation of lima beans as well as its consumption/utilization in order to help curb food insecurity.

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