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Some Functional and Physical Properties of Selected Underutilised Hard-To-Cook Legumes in Nigeria

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Abstract
Four underutilised hard-to-cook legumes were analysed for some physical and functional properties. The seed length ranged from 0.62cm for *Canavalia ensiformis* to 0.99 cm for *Sphenostylis sterocarpa.* The highest water absorption capacity of 28.87% and oil absorption capacity of 9.97% were reported for *Canavalia ensiformis*. The thickness of the legumes ranged from 0.47 cm for *Cassia hirsutta* to 0.72 cm for *Canavalia ensiformis*. The geometric mean diameter of 7.39 and 7.36 cm were observed for *Canavalia ensiformis and Sphenostylis sterocarpa,* respectively. The lowest protein solubility of 7.50% was recorded at pH 5 for *Canavalia ensiformis* while the highest protein solubility for each of the legumes was recorded in the alkaline medium. The physical properties of legumes are important for the design of equipment necessary for food processing. The underutilised legumes have physical and functional properties which make them potentially ideal for local food uses and industrial food systems.

1. Introduction

Legumes refer to the edible seeds of leguminous plants belonging to the *Leguminousae* family. They are many and varied. In many tropical areas of the world and especially in the less developed countries, legumes which are collectively and commonly known as beans and peas are important sources of dietary protein. They contribute substantially to the protein intake of a significant proportion of the world population, particularly in developing countries (Aletor, 1993). Differences exist in both the types and amounts of legumes produced in each area. However, legumes are worldwide in distribution and one or more of them is consumed regularly in some form practically in every country of the world (Gepts *et al*., 2005). In Sub-Saharan Africa, they are kept as alternative food crops when other crops are out of stock. Legumes are useful components of balanced diets reducing the incidences of cardiovascular diseases, cancers and type II diabetes which are believed to be partly associated with food habits (Polhil, 1994). Legumes are low in fat but are rich sources of fibre and minerals. However, a limiting factor to legume utilisation is the presence of certain antinutritional factors which interfere with the digestive processes and prevent efficient utilisation of the legume proteins (Graham and Vance, 2003). These antinutritional factors include enzyme inhibitors, tannin, lectin, phytic acid, cyanogens and saponin.

The legume seed samples *Cassia hirsutta (sese omode); Canavalia ensiformis (sese-nla); Vigna racemosa (gbomagungi); and Sphenostylis sterocarpa (somona/sese)* were some of the lesser known underutilised legumes in Nigeria. Apart from the presence of antinutritional factors, another limiting factor to their utilisation is the prolong cooking times. They are hard to cook. These underutilised legumes are not available in much commercial quantity but are rather found with peasant farmers in villages where they are cultivated mainly for subsistence purposes.

Knowledge of physical properties is essential to facilitate and improve the design of the equipment for harvesting, processing and storage of the crops. Various types of cleaning, grading and separation operations are designed on the basis of physical properties. The functioning of many types of machines is influenced decisively by the size, shape and density characteristics of the material (Yalcin and Orzarslan, 2004). Design of new processing machineries and adaptation of existing ones effectively utilise the potential of these materials in product development. Physical properties of food stuffs play a significant role in modelling and computation of heat and mass transfer in basic food processing and freezing (Yalcin and Orzarslan, 2004; Yadahally *et al.,* 2008). The physical properties of legumes are therefore the pre-requisites on the designing of equipment and facilities for harvesting, handling, conveying, separation, drying, aeration, storing and mechanical extraction of oil and other processes. Functional properties give information on how foods behave in a system either as a processing aid or as a direct contributor of product attributes. Most functional properties affect the sensory characteristics of foods or food ingredients during their preparation, processing and storage (Oyebode *et al.,* 2007). Legumes are widely used in the food industry for their many functional properties (Chef-Guerrero *et al.*, 2011).

Functional properties are of importance in the development of new industrial food products. They may be influenced by conditions such as pH, protein source, lipid, methods of drying, concentration, etc. (Yalcin and Orzarslan, 2004 ; Oyebode *et al.*, 2007). Some physical properties of these legumes such as shape, size and specific gravity will help the engineers, food scientists and processors towards achieving efficient process and equipment for clearing, sorting and grading.

2. Materials and Methods

2.1. Samples and Sample Preparation

Fresh and matured legume seeds were purchased from peasant farmers in Atisbo and Saki West Local Government Areas of Oyo State, Nigeria. The four legume seed samples were :*Cassia hirsutta (sese omode); Canavalia ensiformis (sese-nla); Vigna racemosa (gbomagungi); and Sphenostylis sterocarpa (somona/sese).* The legume seeds were dry-cleaned by removing extraneous particles such as stones, stalks, broken seeds, immature seeds and other unwanted materials. They were then packaged in labelled plastic containers in readiness for subsequent experiments.

2.2. Physical Properties of Raw Legume Seeds

2.2.1. Determination of Seed Weight

One hundred seeds of similar sizes were selected. The seeds were counted and carefully weighed using a chemical balance -- Ohaus Adventurer AR3130 (Idowu, 2005).

2.2.2. Determination of Colour

The assessment of the colour of each of the legume seeds were determined using the method described by Xu and Chang (2009).

2.2.3. Determination of Seed Size

To determine the sizes of the seeds, one hundred seeds were randomly selected from the bulk of each sample. The seed sizes in term of the three linear dimensions namely length, L, in millimetre, width, W, in millimetre and thickness, T, in millimetre from each of the 100 selected seeds were measured with a vernier calliper to 0.01 mm (Mohsenin, 2007; Idowu, 2005).

2.2.4. Determination of Geometric Mean Diameter and Degree of Sphericity

The geometric mean diameter and the degree of sphericity of the seeds were carried out by using the following mathematical relationships:

$$D_e = (LWT)^{1/3}$$

$$Ø = \frac{(LWT)^{1/3}}{L}$$

where,

L =length, mm

W =width, mm

T = thichness, mm

(Mohsenin, 2007; Dutta *et al.*, 1998; Conskuner and Karababa, 2007).

2.2.5. Determination of Surface Area

The surface area, S_a, in cm^2 of each of the legume seeds was determined by using the relationship given by Conskuner and Karababa (2007).

$$S_a = \pi D_{e^2}$$

where,

S_a= surface area

π = 3.142

D_e = geometric mean diameter

2.2.6. Bulk Density

The bulk density was determined according to the method described by Eabekun and Ehieze (1997). A 50 g milled sample was put into a 100 ml graduated cylinder. The cylinder was tapped 40–50 times and the bulk density was calculated as weight per unit volume of sample.

2.3. Functional Properties of Legume Seeds

2.3.1. Water Absorption Capacity (WAC)

The water absorption capacity was determined by the method of Sosulski *et al.* (2002) and Onimawo *et al.*, (2003). A 2 g sample of each of the legumes was mixed with 20 ml distilled water, allowed to stand at ambient temperature for 30 min, then centrifuged for 30 min at 2,000xg. Water absorption capacity was thenexpressed as percentage waterabsorbed per gram sample.

$$\%\ WAC = \frac{V_1}{V_2} \times \frac{100}{1}$$

where,

V_1 = volume of water absorbed, cm^3

V_2 = volume of water used, cm^3

2.3.2. Oil Absorption Capacity (OAC)

The oil absorption capacity was also determined by using the method described by Sosulski *et al.* (2002) and Onimawo *et al.*, (2003). Two grammes of the sample was mixed with 20 ml refined soybean oil of known specific gravity. It was then allowed to stand at ambient temperature for 30 min and then centrifuged for 30 min at 2000xg. Oil absorption capacity (OAC) was expressed as percentage oil absorbed per gram sample.

$$\%\ OAC = \frac{V_1}{V_2} \times \frac{100}{1}$$

where,

V_1 = volume of oil absorbed, cm^3

V_2 = volume of oil used, cm^3

2.3.3. Foaming Capacity (FC) and Foaming Stability (FS)

The foaming capacity (FC) and foaming stability (FS) of the samples were determined using the method described by Narayana and Narasinga (2002); Onimawo *et al.* (2003) and Yusuf *et al.* (2007). Two grammes of the sample was added to 50 ml distilled water in a 100 ml graduated cylinder. The suspension was then mixed and shaken for 5 min to foam. The volume of foam at 30 s after whipping was expressed as foaming capacity using the following formula:

$$FC = \frac{V_2 - V_1}{V_1}$$

where,

V_1 = volume of foam before whipping, cm^3

V_2 = volume of foam after whipping, cm^3

The volume of foam was recorded one hour after whipping to determine foaming stability as a percentage of the initial foam volume.

2.3.4. Hydration Capacity and Hydration Index

One hundred seeds of the legume were counted and weighed. The seed were then transferred into a measuring cylinder. About 100 ml of distilled water was added. The cylinder was then covered with an aluminium foil and allowed to stay for 12-18 h at room temperature. The water was decanted; superfluous water was removed with the aid of filter paper. The seeds were then weighed and the hydration capacity calculated using the following expressions :

$$HC = \frac{W_2 - W_1}{n} (g / seed)$$

where,

W_1 = weight of seeds before soaking

W_2 = weight of seeds after soaking

n = number of seeds

The hydration index (HI) was calculated using the formula below:

$$HI = \frac{HC}{W}$$

where,

HC = Hydration Capacity per seed

W = Weight of one seed (g)

2.3.5. Swelling Capacity

The swelling capacity was determined by the method described by Sathe *et al.* (1982). A 100 ml graduated cylinder was filled with flour sample to the 10 ml mark. Distilled water was added to give total volume of 50 ml. The top of the graduated cylinder was tightly covered and mixed by inverting the cylinder. The suspension was inverted again after 2 min. The volume occupied by the sample was recorded after 8 min. and expressed as swelling capacity.

2.3.6. Protein Solubility

One gram of defatted sample was dispersed in 20 ml of distilled water and allowed to mix on a magnetic stirrer for 5 min. The pH of the resulting slurry was adjusted to the desired pH (between 2 - 20) using 0.1M HCl or 0.1M NaOH. The insoluble materials were removed by placing in the centrifuge (Uniscope model- SM 902B) at 3,500 rpm for 30 min. The supernatant was digested and the nitrogen determined by Kjeldahl method (Leonard *et al.*, 1987; 0yebode, 2005).

3. Results and Discussion

3.1. Legume Seed Samples Description

The photograph of each of the legume seed samples used for this study are shown in Plates 1 – 4. For each legume, the following details are provided in Table 1: the botanical name, description of its physical characteristics and the local name by which it is designated in the area of collection.

Plate 1. *Cassia hirsutta – CH (sese omode).*

Plate 2. *Canavalia ensiformis –CE.*

Plate 3. *Vigna racemosa –VR(Gbomagungi).*

Plate 4. *Sphenostylis sterocarpa –SS (Somona.).*

Cassia hirsutta (sese omode) is relatively smaller with grey colour as shown in Plate 1.The seed coat colour of *Canavalia ensiformis (sese-nla)* as shown in Plate 2 is light brown (chocolate) with smooth shining appearance. *Vigna racemosa* (*gbomogungi*) (Plate 3) has a seed coat that is light grey, smooth and glossy in appearance. *Sphenostylis sterocarpa (somona)* as presented in Plate 4 is black-brown in appearance and almost elliptical in shape. Each legume is coded as shown in Table 1.

Table 1. *Legume seed samples, sources of collection and descriptive characteristics.*

S/N	Sample code	Botanical name	Local name	Source of collection	Seed coat colour	Mean weight (in g) of 100 seeds	Seed shape
1	CH	*Cassia hirsutta*	*Sese omode*	Ago-Are, Atisbo LGA.*	Grey, relatively smaller	11.27	Near spherical
2	CE	*Canavalia ensiformis*	Sese-nla	Saki, Saki West LGA*	Chocolate, light brown smooth shining.	27.56	Near elliptical
3	VR	*Vigna racemosa*	Gbomogungi	Ago-Are , Atisbo LGA*	grey, smooth shining	30.47	Near elliptical
4	SS	*Sphenostylis stereocarpa*	S*somona*	Saki, Saki West LGA*	Black brown	30.76	Near elliptical

*Local Government Area

3.2. Physical Properties of the Legumes

Physical properties of seeds are important for the design of equipment necessary for harvesting and post-harvest handling, transportation and processing of agricultural produce into different consumable and marketable food items. Various types of unit operations such as cleaning, grinding and sorting are designed on the basis of the physical properties.

3.2.1.Seed Weights and Sizes

The seed weights and sizes in term of the three linear dimensions (namely: length, width and thickness) are as recorded in Table 2. The mean weight of the seeds ranged from 11.27 g for *Cassia hirsutta* to 30.76 g for *Sphenostylis stereocarpa*. Mean weights of 27.56 g and 30.47 g were recorded for C*analvalia ensiformis* and *Vigna racemosa*, respectively.

In another study, pigeon pea was reported to have mean length of 0.766 cm (Yalcin, 2004).This was lower than those of the legumes studied in this work with the exception of *Cassia hirsutta* with a mean length of 0.62 cm. The seed length of white African yam bean was reported to be 0.837

cm while that of white lima bean was 1.636 cm (Dutta *et al.,* 2002).

Table 2. *The seed weights and sizes of selected underutilsed legumes.*

	Mean weight of 100 seeds(g)	Length(cm)	Width (cm)	Thickness (cm)
Cassia hirsutta (CH)	11.27a ±1.330	0.62a±0.042	0.60a±0.023	0.47a±0.032
Canavalia ensiformis (CE)	27.56b ±2.342	0.85ab±0.852	0.70a±0.023	0.72d±0.043
Vigna racemosa (VR)	30.47c±2.120	0.89ab±0.060	0.70a±0.44	0.66cd±0.046
Sphenostylis ssterocarpa (SS)	30.76c ±1.936	0.99bc±0.030	0.69a±0.059	0.62bc±0.021

Values are means of three replicates ± standard deviation ; means with different letters in the same column are significantly different (p<0.05).

The lowest value of width of 0.60 cm was observed for *Cassia hirsutia* while the highest value of 0.70 cm was observed for CE and VR. There was no difference (p<0.05) in the width of *Canavalia ensiformis* and *Vigna racemosa* as the two legume seeds had 0.70 cm. These values were lower than 1.20 cm reported for a brown specie of bambara groundnut (Dutta *et al*., 2002).

Measurement of thickness of the legume seeds revealed that CE had the highest value of 0.72 cm while the lowest value of 0.47 cm was recorded for CH. The thickness of *Vigna racemosa* and SS 0.66 cm and 0.62 cm, respectively. The average thickness of 0.566 cm reported for white African bean by Dutta *et al*., (2002) was comparable to those of the legumes reported in this study. However, Flax seed has been reported to have a thickness of 0.85 cm (Conskuner and Karababa, 2007).

3.2.2. Other Physical Properties of the Legume Seeds

Table 3 shows other physical properties of the legume seeds.

The geometric mean diameter for each of the legume samples ranged from 5.49 mm for *Cassia hirsutta* to 7.39 mm for CE. The geometric mean diameters of 7.39 mm, 7.29 mm and 7.36 mm were recorded for *Canavalia ensiformis,* V*igna racemosa* (VR) and *Sphenostylis stereocarpa* (SS), respectively. Pigeon pea, white Africa yam bean and lima bean (brown) were reported to have geometric mean diameters of 5.60 mm, 6.84 mm and 12.25 mm, respectively. Similarly, black bambara nut was found to have geometric mean diameter of 11.31 mm. (Akinci *et al.,*2004 ; Yalcin and Orzarslan, 2004).

Significant difference (p<0.05) was observed in the surface areas of the species of legumes used in this study. These values were slightly lower than the average value of 395.20 mm^2 for Bambara groundnut (black) reported by earlier workers (Yalcin and Orzarslan, 2004; Akinci *et al.,* 2004). This was probably due to varietal differences.

Table 3. *Some physical properties of the legume seeds.*

Legume samples	Geometric mean diameter (mm)	Surface area(mm^2)	Degree of sphericity (mm)	Loose bulk density (g/cm^3)	Packed bulk density (g/cm^3)
Cassia hirsutta (CH)	5.49a±0.624	94.64a±2.632	0.885d±0.043	0.650cd±0.036	0.791c±0.056
Canavalia ensiformis (CE)	7.39b±0.529	171.48d±0.983	0.869cd±0.051	0.689d±0.063	0.869f±0.011
Vigna racemosa (VR)	7.29b±0.667	166.87b±3.012	0.819cd±0.031	0.669cd±0.052	0.827e±0.029
Sphenostylis sterocarpa (SS)	7.36b±0.610	170.09c±1.264	0.743bd±0.031	0.660cd±0.046	0.831e±0.044

Values are means ± standard deviation (n=3); means with different letters in the same column are significantly different (p<0.05).

Among the legumes studied, *Cassia hirsutta* had the lowest surface area of 94.64 mm2. Surface areas of 170.09 mm2 and 171.48 mm^2 were recorded for *Sphenostylis stereocarpa* and *Canavalia ensiformis*, respectively.

The highest degree of sphericity 0.885 mm was recorded for *Cassia hirsutta* (CH). This was closely followed by *Canavalia ensiformis* (CE) and *Vigna racemosa* (VR) with 0.869 mm and 0.819 mm, respectively. It is therefore important to note that design and construction of meshes to handle these legume seeds efficiently during industrial handling and processing should be elliptical in shape rather than circular as commonly available for most seeds.

The loose bulk density gives an indication of the lowest attainable density without compression while the packed bulk density represents the highest attainable density with compression. The results of the loose and packed bulk densities are as recorded in Table 3. As expected for all the samples studied, values for packed bulk densities for each of the legume samples were higher than those of loose bulk densities. Legume samples CH had the least loose and packed bulk densities of 0.650 g/cm^3 and 0.791 g/cm^3, respectively.

As shown in Table 3, the values of loose bulk density were lower than those of the packed bulk density for each of the legume seeds studied. Loose bulk density values ranged from 0.650 g/cm3 for CH to 0.689 g/cm3 for CE. Packed bulk density values ranged from 0.791 g/cm for CH to 0.869 g/cm3 for CE. Flours with low bulk density have been said to be desirable for the preparation of weaning foods because they give reduced/low paste thickness and viscosity on reconstitution (Abass *et al*., 2009). On the contrary, foods that have high bulk density have economic advantage in terms of packaging. It has also been reported that foods of high bulk density enhance fat absorption which is not a good attribute for weaning foods. The enhancement of fat absorption by high density foods is an important desirable attribute for flour used for baked and pastry products (Abass *et al*., 2009). Therefore, flours of low bulk density prepared from legume samples such as CH, and SS should be used for the preparation of weaning foods while flours from SS and VR should be more appropriate for local dishes such as *towobepo*, *kengbe* and pastry products where high density constitutes a commercial advantage.

3.3.Functional Properties

3.3.1. Water Absorption Capacity

With reference to Table 4 the water absorption capacity (WAC) of the legume seed flours ranged from 155.6% to 288.7% with sample *Canavalia ensiformis* (CE) having the highest value and *Sphenostylis sterocarpa* (SS) having the lowest value. The WAC of *Cassia hirsutta* (CH) and *Vigna racemosa* (VR) were 266.4% and 216.3%, respectively. These values were higher than the values reported for soy flour – 130% and pigeon pea – 130% (Oshodi *et al*., 1999). Similarly, Oyebode *et al.* in 2007 reported WAC of 237.50% for *Adenopus benth* seed and 197.50% for lima bean. The presence of fat, though in small quantity, may be responsible for the moderate quantity of WAC of each of these legume samples. It has been reported that defatting of seeds led to increase in the WAC. This was true for *Adenopus benth* seed flour that had the WAC changed from 237.50% before defatting to 397.50 after defatting (Oyebode *et al*., 2007).

Protein isolate from lima bean also had higher WAC of 379.00% compared with the raw flour from lima bean – 197.50%. These results agree with the findings of Hermanson (2002) that it was not only protein materials that is responsible for changes in WAC and that high protein solubility does not necessarily result in high WAC. The relationship between the content of hydrophilic group of proteins and WAC had been established which gave the indication that legume plants rich in protein have more hydrophilic groups exposed to water (Hermanson, 2008 ; Oyebode *et al.,* 2007). Therefore, the flours or protein isolates of these underutilised hard-to-cook legumes would be useful in enhancing the water binding capacity of food products like dough and sausages.

3.3.2. Oil Absorption Capacity

Table 4 shows the oil absorption capacity (OAC) of the legume seed flours ranging from 54.5% for *Cassia hirsutta* to 99.7% for *Canavalia ensiformis*. Oil absorption capacity is the binding of fat by non-polar side chain of proteins. It gives a useful indication of whether the food or protein material will perform well as a meat extender or analogues. The values of oil absorption capacities in this research work are lower than flours of jack bean (105%), cowpea (240%) and Lupin seed (167%) (Fagbemi and Oshodi, 1991; Oshodi and Ekperingin, 1994). Also, Oyebode (2005) reported oil absorption capacity of 197.50% for lima bean and 225.00% for *Adenopus benth seeds*. Higher values were also reported for plantain flour 214% - 317% (Fagbemi, 1999). In spite of these low values, the values obtained in this study were comparable with those of some other legumes and oil seed flours in the range of 50% - 150% (Sathe *et al.,* 1982; Oshodi and Ekperingin, 1994; Fagbemi and Oshodi, 1991). Deffating of legume seed flours from lima and *Adenopus benth* seed and isolation of proteins caused significant increase in the oil absorption capacity (Oyebode, 2005). This could be due to the higher concentration of protein in the deffated flours of legume samples.

Oil absorption capacity of food is attributed to the physical entrapment of oil which is considered important as a flavour retainer and improves mouth feel of foods. Flours from legume samples that had OAC of more than 6.0% have been reported to perform well in formulation of meat extenders and bakery products (Oyebode, 2007; Yadahally *et al.*, 2008). Therefore, the oil absorption capacities of these legume flours, especially those from *Canavalia ensiformis, Vigna racemosa* and *Sphenostylis sterocarpa* (SS), with oil absorption capacities of 9.97, 7.08 and 8.02%, respectively, give an indication that they might be useful in ground meat formulation, meat replacers or extenders. They could also perform well in bakery products such as cake and doughnut, formulation of ingredients as well as in foods that involve oil mixing where oil is an important ingredient or when oil is the mobile phase of an emulsion.

Therefore, the use of flours from these legumes such as *Canavalia ensiformis* and *Sphenostylis sterocarpa* (SS) with high oil absorption capacities will be desirable for local dishes such as *akara towobepo and seke.*

Table 4. *Functional properties of the selected underutilised legumes.*

Legume samples	WAC (%)	OAC (%)	FC (%)	FS (%)	HC(g/seed)	HI(per seed)	SC
Cassia hirsutta (CH)	6.64g±1.020	5.45a±0.871	8.00d±0.989	3.00c±0.622	0.081b±0.002	0.721d±0.056	27.21b±2.24
Canavalia ensiformis(CE)	28.87h±1.564	9.97e±0.779	3.70b±0.396	1.85b±0.401	0.013a±0.001	0.045a±0.004	19.43a±1.93
Vigna racemosa (VR)	21.63e±1.056	7.08c±0.585	3.85b±0.656	2.08b±0.457	0.154c±0.010	0.503c±0.198	28.57c±3.01
Sphenostylis sterocarpa (SS)	15.56b±0.624	8.02d±0.724	3.64b±0.421	1.82b±0.555	0.117b±0.012	0.380b±0.012	58.30d±3.22

Values are means of three replicates ± standard deviation; means with different letters in the same column are significantly different (p <0.05).
WAC=water absorption capacity; OAC=oil absorption capacity; FC= foaming capacity;FS= foaming stability; HC= hydration capacity; HI= hydration index; SC= swelling capacity.

3.3.3.Foaming Capacity and Foaming Stability

The results of the foaming capacity (FC) and foaming stability (FS) tests for each of the legume samples are recorded in Table.4. Foaming capacity (FC) is the increase in volume upon the introduction of air or a gas into the slurry of a given food or its dispersion while foaming stability (FS) refers to the ability of foam formed to retain its maximum volume over time. The highest values of foaming capacity and foaming stability of 8.00 and 3.00%, respectively were recorded for CH while the lowest values of 3.64 and 1.82% of foaming capacity and foaming stability, respectively, were recorded for *Sphenostylis sterocarpa* (SS). The foaming capacity of 3.70 and 3.85% were obtained for *Canavalia ensiformis* (CE) and *Vigna racemosa,* respectively. All the samples had low ability to retain foam after whipping.

The presence of fat ranging from 0.91% to 6.85% in these legume flours might be responsible for the low foaming capacity and stability observed. This finding is in consonance with the work of Oshodi *et al.,* (1999) and Fagbemi (1999) in which the deffated flour samples of some legumes and grains such as sorghum and pearl millet were found to have higher foaming capacity than their counterpart full fat flour samples. However, Onigbogi and Adesina (2006) reported foaming capacity and foaming stability values of 17.65 and 82.00%, respectively, for cowpea and 0.55 and 50.00%, respectively, for defatted soy flour. Protein isolates of lima bean and *Adenopus brevifolus* benth seeds have also been found to have higher foaming capacity (Oyebode, *et al.,* 2005 ; Oshodi *et al*., 1999).

In addition to the nature and quantity of protein and fat, there are other factors that can influence the foaming properties of foods. These include pH, method of processing, temperature, whipping method, presence or absence of sugar and salt such as calcium ion, duration ofheating as well as solubility (Fernema (1996).

3.3.4. Swelling Capacity

The swelling capacity (SC) of each of the underutilised legumes studied is as recorded in Table 4. Swelling capacity gives an indication of increase in the volume upon absorption of water. It is a very important parameter when changes in volume after processing enhance the acceptability of the final product.

Canavalia ensiformis had the lowest value of swelling capacity --19.43%. The swelling capacities of *Cassia hirsutta* (CH), *Vigna racemosa* and *Sphenostylis sterocarpa* (SS) were 27.21%, 28.57 and 58.30%, respectively. Soaking of cowpea (*Vigna unguiculata*) at different pH to remove the hull during preparation of *akara* was reported to affect the swelling ability of the cowpea flour. Flour produced from cowpea soaked at lower pH had higher swelling ability than that from cowpea soaked at pH 9.50 (Uzoechima, 2006). Decrease in swelling capacity due to changes in the pH of soaking solutions affected the degree of acceptability of *akara* fried using the flour samples (Uzoechima, 2006).

Onigbogi and Adesina (2006) made a progressive dilution of cowpea flour with defatted soybean flour to produce blends for *akara*. Although the progressive addition lowered the bulk density, there was only marginal increase in the swelling capacity of the blends on hydration. It was reported that observed changes in swelling capacity resulting from supplementation with soybean, induced changes in the properties of the final products.

It could therefore be inferred that flours from legumes such as *Sphenostylis sterocarpa* with high swelling capacity will be appropriate for the production of such local dishes as *akara* and *moinmoin* where the volume of the final product is of economic advantage. A flour derived product with high swelling capacity or index has comparative advantages over those with low swelling capacity.

3.3.5. Hydration Capacity and Index

Hydration index for each of the legumes sudied is recorded in Table 4. Hydration index ranged from 0.045 for *Canavalia ensiformis* (CE) to 0.721 for CH. Hydration Index (HI) for *Sphenostylis sterocarpa* (SS), and *Vigna racemosa* (VR) and *Cassia hirsutta* are recorded as 0.380, 0.50, respectively.

3.3.6. Protein Solubility

The protein solubility profiles of the legume seed samples studied as affected by changes in pH are recorded in Figure 1.

The highest percentage solubility of 17.60 and 18.00 were recorded in the alkaline medium of pH 12 for *Cassia hirsutta* (CH) and *Vigna racemosa* (VR), respectively. At pH 12, samples CE and SS had the solubilities of 12.00 and 13.44, respectively.

The protein solubility profiles as shown in Figure 1 revealed that each of the legume seed samples studied had the highest solubility at alkaline medium. This was true for all the samples studied. These findings agree with the results of Oyebode (2005) for another legume, *Adenopus benth* seed. Similar research work carried out by Oshodi and Adeladun (1993) for lima bean showed highest solubility of the legume in alkaline medium. The more soluble the protein the better would be its functionality in food system. Good protein solubility of these legumes in alkaline medium is an indication that the protein isolates for each of the legumes could be extracted by alkaline extraction followed by precipitation at their isoelectric pH. Although the highest solubility for all the samples is in the alkaline medium, the legume seed samples are both soluble in acid and alkaline media signifying the seeds and or their protein isolates could be used in formulation of acid and non-acid foods.

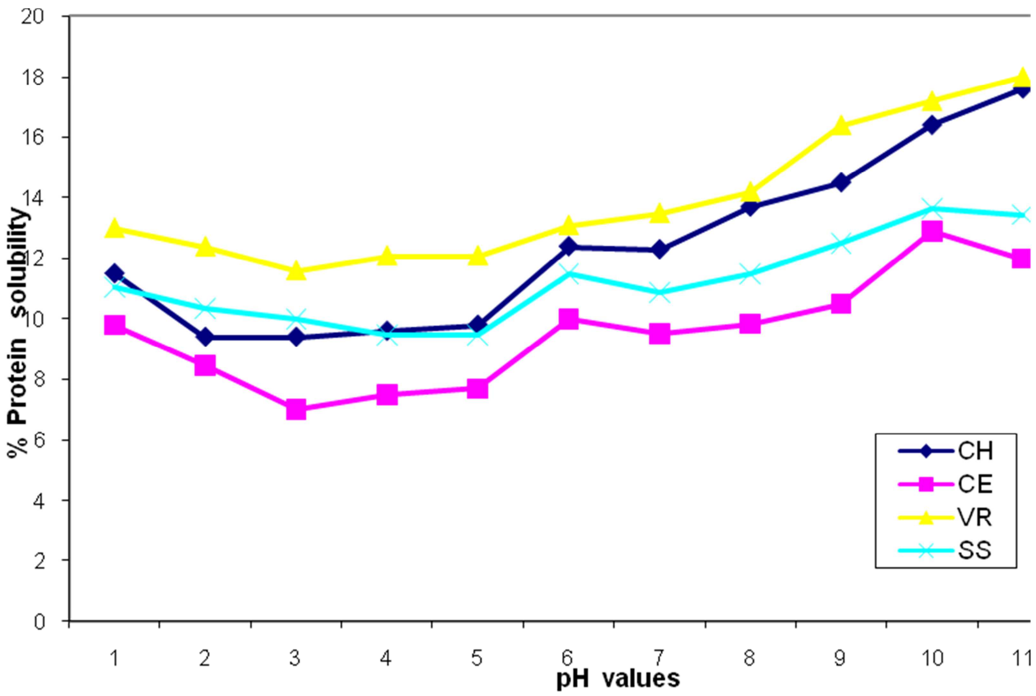

Figure 1. *Effect of pH on protein solubility of selected legumes.*

CH= *Cassia hirsutta (sese omode)* ;
CE=*Canavalia ensiformis (Sese-nla);*
VR=*Vigna racemosa (Gbomagungi)* ;
SS=*Sterocarpa sphenostylis— (Somona*).

4. Conclusion

The knowledge of various physical properties of legumes is important and provides as much data required for the design of various processing machines, processes and control in developing new consumer products and in evaluating and retaining the quality of final products as well as very essential for the design of components of machines. Flour from legume such as CH with relatively low bulk density may be appropriate for formulation of infant foods where low paste thickness and low viscousity constitute an advantage whereas flours with high bulk density should be be more desirable for pastries and local dishes such as *akara kengbe*, *towobepo* and *gbegiri.* The functional properties of the legumes gave indication of how they would behave in a food system. Although the legumes studied are more soluble in the alkaline medium, they are promising crops that could be utilised in the formulation of both acid and alkaline foods. The underutilised legumes studied have the potential of being used in the formulation of new foods and feeds which will foster economic utility. Utilisation of these legumes could complement and or replace certain species of legumes such as soybean and common bean that are widely used in the food industry for their many functional properties (swelling, foaming, emulsion capacities) which impart textural and quality characteristics. Further researches should determine the best ways to tailor their formulations.

References

[1] Abass, F. M. A, Saidullah, R. and Azhar, M. E. (2009). Assessment of physical properties of ripe banana flour prepared from two varieties :Cavedish and Dream bananas. International Food Research Journal, 16:183-189.

[2] Akinci, I., Ozdemir, F., Topuz, A., Kabas, O. and Cankci, M. (2004). Some physical and nutritional properties of *Juniperus drupacea*fruits. Journal of Food Engineering, 65;325-331.

[3] Aletor, V. A. (1993). Allelochemical in plant food and feeding stuffs: Nutritional, biochemical and psychopathological aspects in animal production. Journal of Vetenary and Human Toxicology . 35: 57 – 67.

[4] Chef-Gurrero,A., Gallegos-Tintore, S., Martinez-Ayala, A., Castellanos-Ruella, A. and Betencur-Ancona (2011). Funtional properties of lima bean (*Phaseolus lunatus* L.) seeds. Food Science and Technology International Vol. 17 No. 2, pp 119-126.

[5] Conskuner, Y. and Karababa, E. (2007). Some physical properties of Flaxseed (*Linum usitatissimum*L.). Journal of Food Engineering, 78, 1067-1073.

[6] Dutta, S. K., Nema, V. .K., Bhardway, R. K. (2002). Some physical properties of grain. Journal of Agricultural Engineering Research, 43, 128 137.

[7] Eabekun, M. K. and Ehieze, M. U. (1997). Proximate composition and functional properties of full fat deffated beni seed (*Sesmum indicum L.*) Plant Foods Num. Nutr. 51:35-40.

[8] Fagbemi, T. N. and Oshodi, A. A. (1991). Chemical composition and functional properties of full fat fluted pumpkins (*Telfaria occidentalis*) seed flour. Nig. Food J.9:26-32.

[9] Fagbemi, T. N. (1999). Effect of blanching and ripening on functional properties of plantain flour. Plant Foods for Human Nutrition. 54, 261-269.

[10] Gepts, P., Beavis, W. D., Brumones, E. C., Shoemaker, R. C., Stalker, H. J., Weeden, N. F. and Young, N. D. (2005). Legumes as a nodule plant family. Genomics for food and feed report of the cross legume advances through genomics conference. Plant Physiology 137: 1228 – 1235.

[11] Graham, P. H. and Vance, C. P. (2003). Legumes: Importance and constraints to greater use. Plant Physiol. 131: 872 – 877.

[12] Hermanson, A. M. (2002). Functional properties of protein for food swelling lebensin. Wiss. Technol. 51: 24.

[13] Idowu, M. A. (2005). An investigation into some factors affecting quality and storage characteristics of "orunla" [okra (*Abelmoschus esculentus*)] powder. A Ph.D. thesis submitted to the department of Food Science and Engineering, Ladoke Akintola University of Technology, Ogbomoso. Pp.35-42.

[14] Leonard, W. A., Woods, A. E. and Marion, R. W. (1987). Food Composition and Analysis.Van Nostrand Reinhold, NewYork. Pp. 232-280.

[15] Mohsenin, N. N. (2007). Physical properties of plant and animalmaterials. Gordon and Beach. Science Publishers, New York.

[16] Narayana, K. and Narasinga, R. (2002). Functional properties of raw and heat processed winged bean (*Psophocorpus tetragonolobus*). J. Food Sci. 47: 1534 – 1538.

[17] Onigbogi, I. O. and Adesina, A. (2006). Functional properties of cowpea/soybean flour blends for *Akara* processing. Proceedings of the 30th Annual conference/general meeting of Nigerian Institute of Food Science and Technology, Lagos. pp. 77-78.

[18] Onimawo, I. A., Nmerole, E. C. ,Ndoko, P. I. and Akubor, P. I. (2003). Effects of fermentation on nutrients content and some functional properties of pumpkin seed (*Telfaria occidentalis*). Plant Foods for Human Nutrition, 58: 1-9.

[19] Oshodi, A. A. and Adeladun, M. O. (1993). Proximate composition of some nutritionally valuable minerals and functional properties of three varieties of lima bean (*Phaseolus lunantus*). Int. J. Food Sci. & Nutr. 43: 181-185.

[20] Oshodi, A.A. and Ekperingin (1994). Functional properties of protein concentrates: albunin and globulin obtained from pigeon (*Cajanus cajan*) seed. Nig. J. Sci. 28; 43-47.

[21] Oshodi, A. A., Ogungbenle, H. N. and Oladimeji, M. O. (1999). Chemical composition, nutritionally valuable minerals and functional properties of benniseed (*Sesamum radiatum*), pear millet (*Pennisetum typhoides*) and quinoa (*Chenopodium quinoa*) flours. Int. J. Food Sci. & Nutr. 50;325-331.

[22] Oyebode, E. T., Ojo, M. A. and Oshodi, A. A. (2007). Physico chemical properties and *in-vitro* protein digestibility of flours and protein isolate from *Adenopus breviflorus* Benth seed. Science Focus, Vol. 12 (1), Pp. 28-34.

[23] Polhill, R. M. (1994). Classification of the *Leguminosae*. In Phytochemical Dictionary of the Leguminosae (Bisby. F.A.; Bucking-harm, J. and Harbone, J.B., eds.). Chapman and Hall, New York. pp. 152 – 157.

[24] Sathe, S. K., Deshpande, S. S. and Salunkhe, D. K. (1982). Functional properties of lupin seed. Journal of Food Science 47: 491 – 497.

[25] Sosulski, F. W., Elkowicz, L. and Reichert, R. D. (2002). Oligosaccharides in eleven legumes and their air-classified protein and starch fractions. J. Food Sci. 47: 498 – 502.

[26] Uzoechina, O. B. (2006). Physiochemical characteristics of flours from alkali soaked cowpea (*Vigna unguiculata*) seeds and organoleptic quality of a*kara* made from them. Proceedings ofthe 30th Annual conference/general meeting of Nigerian Institute of Technology, Lagos. pp. 85-86.

[27] Xu, B. and Chang, S. K. C. (2009). Phytochemical profiles and health-promoting effects of cool-season food legumes as influenced by thermal processing. J. Agric. Food Chemistry, 57, 10718-10731.

[28] Yadahally, N. S., Vadakkot, B. S. and Vishwas, M. P. (2008). Expansion properties and ultrastructure of legumes: effects of chemical and enzyme pre-treatments. Food Sci. and Tech. 30: 1 -6.

[29] Yalcin, I. and Orzarslan, C. (2004). Physical properties of vetah seed. Journal of Biosystem Engineering, 88(4), pp 507-512.

[30] Yusuf, A. A., Folarin, O. M. and Bamiro, F. O. (2007).Chemical Composition and Functional Properties of snake gourd (*Trichisanth escucumerina*) seed flour. Nigerian Food Journal, 25(1), 36-45.