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# Assessment of Some Physical and Functional Properties of Two Species of *Vigna subterranean* – An Underutilised Hard-to-Cook Legume in South-West Nigeria

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***Abstract:***
*Some physical and functional properties of two species of Vigna subterranean -- light cream smooth (VS1) and cream mottled with brown (VS2) varieties, were determined. The mean weight of 75.83 and 80.11 g was recorded for VS1 and VS2, respectively. Geometric mean diameter, surface area and degree of sphericity were significantly higher (p<0.05) for VS2 than for VS1. However, packed bulk density was higher for VS1 (0.758 g/cm3) than VS2 (0.627 g/cm3). Water absorption capacity of 18.38 and 13.07 % were recorded for VS1 and VS2, respectively while oil absorption was higher for VS2 (8.31%) than VS1 (6.20%). Foaming capacity of 3.92% was observed for VS1 while VS2 had 1.96%. Swelling capacity was higher for VS2 (80.00%) than for VS1 (75.71%). The protein solubility profiles of VS1 and VS2 are similar and at the highest in the alkaline medium. Solubility of each of the species decreased with increase in pH until isoelectric point was reached followed by increase in solubility with increase in pH. Adoption of these lesser known legumes will foster industrial utility and strengthen dietary diversity.*

***Keywords:*** *Vigna subterranean, legumes, underutilised, physical, functional properties*

## 1. Introduction

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. Occurrence of protein energy malnutrition in many developing nations of the world is on the increase because of increase in population and inadequate supply of protein. In recent times, much attention is being given to the wide prevalence of protein energy malnutrition in developing countries by food scientist and nutritionist (Aletor, 1993; Adebowale *et al*., 2005). Recent studies have shown that malnutrition among children in developing countries is mainly due to high consumption of cereal based porridge which is bulky and high in antinutrients. ( Adebowale *et al*., 2005). Protein can be obtained from plant and animal sources. Animal protein is more expensive and thus outside the reach of a large segment of population in many developing areas of the world. Because plant protein products are relatively cheaper, they are gaining increased interest as ingredients in food systems in many parts of the world.

Among the families of plants, legumes are the most utilised as alternative sources of protein. Human consumption of legumes has been increasing in recent years since the seeds are regarded as a source of beneficial nutrients (Lewis et al., 2005; Gept *et al*.,2005). Legumes reduce the incidences of cardiovascular diseases and cancers. They are also good sources of protein and minerals. Frequent intake of legumes may lower blood cholesterol concentration significantly (Polhil, 1994).

*Vigna subterranean* is one of the underutilised edible legumes in Nigeria belonging to the families of *Fabaceae* or *Leguminousae*. It is popularly called Bambara after the Bambara tribe in Mali. Apart from being a good source of protein, *Vigna subterranean* is also rich in minerals fibre and carbohydrates (Ojo *et al*., 2014)

In our previous study, the nutrients and phytochemical components of some underutilised legumes have been reported (Ojo *et al*., 2014). In continuation of our work on underutilised tropical legumes, efforts have been made in this study to examine the physical and functional properties of two species of *Vigna subterranean*. Post harvesting and industrial processing of this underutilised legume would require a number of equipment and the design of such equipment demands understanding of the physical and functional properties of the seeds (Sandra *et al.*, 2012). Knowledge of physical and functional properties would provide useful information on how food behave in a system either as a processing aid or as a direct contributor of product attributes. The success of using plant proteins as additives depends greatly upon the favourable properties they impart to foods (Adebowale *et al*., 2005)

## 2. Materials and Methods

### *2.1. Samples and Sample Preparation*

Matured seeds of two species of *Vigna subterranean* (*Bambara groundnut*) -- *cream coloured variety* and *chequered coloured variety*, were obtained from peasant farmers in Irawo, Atisbo Local Government Area of Oyo State, Nigeria. 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 Sizes

To determine the sizes of the seeds, one hundred seeds were randomly selected from the bulk of each sample. The seed sizes in terms 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 0.01mm. (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:

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

$$Ø = \frac{(LWT)^{1/3}}{L}$$

(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).

$$S_a = \pi D_e^2$$

#### 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 volume occupied by the sample was noted 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 then expressed as percentage water absorbed per gram sample.

$$\% \text{ WAC} = \frac{\text{vol. of } H_20 \text{ absorbed}}{\text{vol. of } H_20 \text{ used}} \times \frac{100}{1}$$

#### 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.

$$\% \text{ OAC} = \frac{\text{Vol. of Oil absorbed}}{\text{Vol. of Oil used}} \times 100$$

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:

$$\text{Foaming capacity} = \frac{\text{volume of foam after whipping} - \text{volume of foam before whipping}}{\text{Volume of foam before whipping}}$$

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 :

$$\text{Hydration capacity per seed} = \frac{W_2 - W_1}{n} \quad \text{(g/seed)}$$

$W_1$ = 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:

$$\text{HI} = \frac{\text{Hydration Capacity per seed}}{\text{Weight of one seed (g)}}$$

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; Oyebode, 2007).

## 3. Results and Discussion

### *3.1. Legume Seed Samples Description*

The photograph of the legume seed samples used for this study are shown in Figures 1 and 2. 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.

*Vigna subterranean* (VS1), a specie of bambara groundnut has cream colour mottled with brown. It is presented in Figure 1. *Vigna subterranean* (VS2) (Figure 2) is another specie of bambara groundnut. It's appearance is creamy and smooth. The shape of the seeds of the two varieties appeared similar and spherical. Each legume is coded as shown in Table 1.

*Figure 1: Vigna subtterranean—VS 1 (Bambara groundnut, Cream coloured variety )*

*Figure 2: Vigna subtterranean—VS2 (Bambara groundnut, mottled coloured variety)*

| S/N | Sample Code | Botanical name | Local name | Source of collection | Seed coat colour | Mean weight (in g) of 100 seeds | Seed shape |
|---|---|---|---|---|---|---|---|
| 1 | VS1 | *Vigna subterranean* | *Bambara* | Irawo Atisbo LGA | Cream mottled with brown. Light | 75.83 | Near spherical |
| 2 | VS2 | *Vigna subulatus* | *Bambara* | Irawo Atisbo LGA | Cream, smooth | 80.11 | Near spherical |

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

*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. Seeds Weights and Sizes

The seed weights and sizes in terms of the three linear dimensions (namely: length, width and thickness) are as recorded in Table 2. It was observed that cultivars of the same species, had significant difference (p <0.05) in the mean weights. There was a significant difference in the mean weights of the two cultivars of bambara groundnuts. While *Vigna subterranean* (VS1) had a mean weight of 75.83 g, *Vigna subterranean* (VS2) had a mean weight of 80.11 g.

The two cultivars of bambara groundnut VS1 and VS2 were similar measuring 1.15 cm and 1.22 cm, 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 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).

| | Mean weight of 100 seeds (g) | Length (cm) | Width (cm) | Thickness (cm) |
|---|---|---|---|---|
| *Vigna subterranean* (VS1) | 75.83a ±1.734 | 1.15a±0.058 | 0.92a±0.053 | 1.00a±0.065 |
| *Vigna subterranean* (VS2) | 80.11b ±1.622 | 1.22b±1.224 | 1.08b±0.096 | 1.13b ±0.063 |

*Table 2 : The seed weights and sizes of the selected underutilised legumes*

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

The mean width values of 0.92 and 1.08 cm were observed for the two varieties of bambara groundnut (VS1 and VS2), respectively (Table 2). These values were comparable to 1.20 cm reported for a brown specie of bambara groundnut (Dutta *et al.*, 2002).

Measurement of thickness of the legume seeds revealed that *Vigna subterranean* (VS2) had the value of 1.13 cm while the lower value of 1.00 cm was recorded for *Vigna subterranean* (VS1). The average thickness of 0.566 cm was reported for white African bean by Dutta *et al.*, (2002) while 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 is as shown in Table 3. There was significant difference ($p$<0.05) in the geometric mean diameter of the two species. The cream coloured specie had geometric mean diameter of 9.92 mm while the mottled coloured had 11.14 mm ranged from 5.49 mm for *Cassia hirsutta* to 11.78 mm for *Mallotus subulatus* (MS1). Geometric mean diameters of 5.72 mm and 5.07 mm were observed for red cowpea and black cowpea, respectively (Saima *et al*, 2014). 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). This value was similar to the value of 11.4 mm obtained for the mottled coloured variety used in this study.

Significant difference ($p$<0.05) was observed in the surface area of the two species of *Vigna subterranean* used in this study. VS1 and VS2 had the surface area of 308.99 $mm^2$ and 389.67 $mm^2$, respectively. These values were slightly lower than the average value of 395.20 $mm^2$ for black bambara groundnut reported by earlier workers (Yalcin and Orzarslan, 2004; Akinci *et al.*, 2004). This was probably due to varietal differences. Surface area is used for designing grader, cleaner and separator for seeds (Saima *et al*, 2014). Thus, the two speceis need different designs of these equipments for their processing.

| Legume samples | Geometric mean diameter (mm) | Surface area ($mm^2$) | Degree of sphericity (mm) | Loose bulk density ($g/cm^3$) | Packed bulk density ($g/cm^3$) |
|---|---|---|---|---|---|
| *Vigna subterranean* (VS1) | 9.92a±0.967 | 308.99a±4.152 | 0.863a±0.051 | 0.623b±0. | 0.758b±0.000 |
| *Vigna subterranean* (VS2) | 11.14b±1.020 | 389.67b±4.278 | 0.913b±0.049 | 0.546a±0.045 | 0.627a±0.008 |

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

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

The degree of sphericity was lower for VS1 (0.863 mm) than for VS2 (0.913 mm). This indicate that the mottled coloured variety was more spherical than the cream coloured. In an earlier study sphericity in the range of 67–79% was reported for various cultivars of cowpea (Davies and Zibokere, 2011).

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 the Table 3. As expected, values for packed bulk densities for each of the varieties were higher than those of loose bulk densities. Legume samples VS2 had lower loose and packed bulk densities of 0.546 $g/cm^3$ and 0.627 $g/cm^3$, respectively while VS1 had loose and packed bulk densities of 0.623 g/cm$^3$ and 0.758 g/cm$^3$, respectively. Black cowpea was reported to have bulk density of 0.82 g/cm$^3$ while red cowpea had 0.72 g/cm$^3$.

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 VS1, and VS2 could be used for the preparation of weaning foods while flours from cowpea with relatively higher bulk density could be more appropriate for local dishes such as *towobepo*, *kengbe* and pastry products where high density constitute a commercial advantage.

### *3.3. Functional Properties*

#### 3.3.1. Water Absorption Capacity

The result of the water and oil absorption capacity of the two species of Vgna subterranean are shown in Table 4. The water absorption capacity (WAC) of the legume seed flours was 18.38% for VS1 and 13.07% for VS2. Intrinsic factors affecting WAC of food protein include size and shape of protein, steric factors, hydrophilic-hydrophobic balance of amino acids in the molecules, and lipids and carbohydrates present in the flour ( Sandra et al., 2012). Presence of fat, though in small quantity, may be responsible for the moderate quantity of WAC of each of these legume samples. Defatting of seeds has been reported to cause increase in the WAC. This was true for *Adenopus bent*h seed flour (Oyebode *et al*., 2007) and some species of *Mucuna* (Adebowale *et al*., 2005). 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, 2002 ; 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.

#### 3.3.3. Oil Absorption Capacity

Significant difference ($p$<0.05) existed in the OAC of the two species of *Vigna subterranean*– VS1 and VS2 with VS1 having 6.20% and VS2 having 8.31%. The OAC was comparable to those reported for vitabosa (1.82 ml/g) and soybean (1.43 ml/g) (Sandra *et al.*, 2012). Oil absorption capacity is the binding of fat by non-polar side chain of proteins. It gives a useful indication of whether the food/protein material will perform well as a meat extender or analogues. Although samples from *Vigna subterranean* (VS1) and *Vigna subterranean* (VS2) are different cultivars of the same species, they have different oil absorption capacity. This suggests that VS2 with relatively higher OAC has more hydrophobic interaction sites than VS1. The difference was probably be due to variations in the presence of non-polar side chains, which might bind the hydrocarbon side chains of oil in the flours (Lawal, 2004; Sadra *et al.*, 2012). ). Deffating of legume seed flours from species of *mucuna*, lima and *Adenopus benth* seeds and isolation of proteins caused significant increase in the oil absorption capacity (Oyebode, 2007). This could be due to the higher concentration of protein in the deffated flours of legume samples.

Deffating of legume seed flours from species of *mucuna*, lima and *Adenopus benth* seeds and isolation of proteins caused significant increase in the oil absorption capacity (Oyebode, 2007). This could be due to the higher concentration of protein in the deffated flours of legume samples. Therefore, the oil absorption capacities of these legume flours give an indication that they might be useful in ground meat formulation, meat replacers or extenders. They could also perform well in bakery products where oil is an important ingredient or when oil is the mobile phase of an emulsion (Fernema, 1996). Therefore, the use of flours from these species be desirable for local dishes such as *gbegiri* soup, *akara towobepo and seke.*

| **Legume samples** | **WAC (%)** | **OAC (%)** | **FC (%)** | **FS (%)** | **HC (g/seed)** | **HI (per seed)** | **SC** |
|---|---|---|---|---|---|---|---|
| *Vigna subterranean* (VS1) | 18.38b±0.814 | 6.20a±0.512 | 3.92b±0.497 | 1.96b±0.357 | 0.384a±0.034 | 0.506a±0.034 | 75.71a±3.52 |
| *Vigna subterranean* (VS2) | 13.07a±0.797 | 8.31b±0.713 | 1.96a±0.397 | 0.16a±0.025 | 0.735b±0.054 | 0.918b±0.557 | 80.00b±3.54 |

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

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.

#### 3.3.4. 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. There was significant difference ($p$<0.05) in the foaming capacity and foaming stability of the two species. Samples VS1 and VS2 had FC of 3.92 and 1.96 %, respectively and FS of 1.96 and0.16%. *Mucuna rajada* was reported to have higher FC of 9.8% (Adebowale *et al.,* 2005).

The presence of fat 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), Fagbemi (1999) and Adebowale *et al.,* (2005) in which the deffated flour samples of some Species of mucuna 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.,* 2007 ; Oshodi *et al*., 1999). It was reported that foamability is related to the rate of decrease of the surface tension of the air/water interface caused by absorption of protein molecules (Sathe et al., 1982).

It is necessary to state, however that according to Fernema (1996), 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 of heating as well as solubility.

3.3.5. Swelling Capacity

The swelling capacity (SC) of each of the species is as presented 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.

Of the two samples studied, VS2 had the higher swelling capacity of 80.00% while VS1 had 75.71%. 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 these two species of *Vigna subterranean* 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.

3.3.6. Hydration Capacity and Index

Hydration index for each of the legumes studied is recorded in Table 4. There was significant difference (p<0.05) in hydration index between VS1 (0.506) and VS2 (0.918). In another study, hydration capacity of *M. deeringiana* and soybean were 0.71 and 0.20 g/seed , respectively while hydration index were 0.74 and 1.19, respectively.

3.3.7. Protein Solubility

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

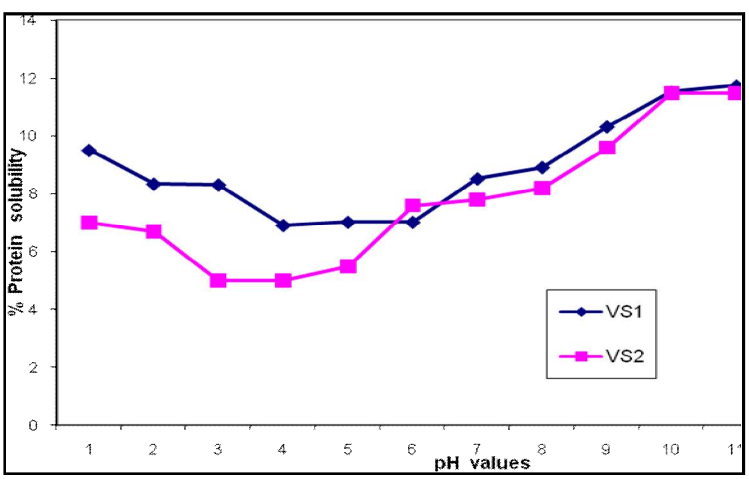


*Figure 3: Effect of pH on protein solubility of Vigna subterranean*
*VS1 = Vigna subterranean— cream coloured variety (Bambara groundnut)*
*VS2 = Vigna subterranean -- mottled coloured variety (Bambara groundnut)*

The protein solubility profiles of VS1 and VS2 are similar. While VS1 had the lowest protein solubility of 6.90% at pH 5, VS2 had the lowest protein solubility of 5.00% at the same pH 5.

The protein solubility profiles as shown in Figures 1 revealed that each of the legume seed samples studied had the highest solubility at alkaline medium. This was true for the two species studied. Solubility of each of the species decreased with increase in pH until isoelectric point was reached followed by increase in solubility with increase in pH. Protein solubility is influenced by prevalent charge on constituents amino acids of protein at different pH. These findings agree with the results of Oyebode *et al.* (2007) 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.

**4. Conclusion**

The knowledge of various physical properties of legumes is important which provides as much data required for the design of various processing machines, processes and control in developing a new consumer product and in evaluating and retaining the quality of final products as well as very essential for the design of components of any machine. Flours from legumes such as VSI and VS2 with relatively low bulk density will 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 which 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.

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