Journal of Food Technology 5 (2): 109-115, 2007

Functional Properties of Some Nigerian Varieties of Legume Seed Flours and Flour Concentration Effect on Foaming and Gelation Properties

[1]M.O. Aremu, [2]O. Olaofe and [2]E.T. Akintayo
[1]Department of Chemistry, Nasarawa State University, P.M.B. 1022, Keffi, Nigeria
[2]Department of Chemistry, University of Ado-Ekiti, P.M.B. 5363, Ado-Ekiti, Nigeria

Abstract: Functional properties of two varieties of Bambara Groundnut Flours (BBG* and BBGF*) Kerstring's Groundnut Flour (KSGF), two varieties of Rear Cowpea Flour (RCPF* and RCPF*) and Scarlet Runner Beans Flour (SRBF) were determined. Effects of flour concentration on foaming and gelation properties were also investigated. The results showed that the functional properties of the varieties of legume seed flours ranged as follows: Foaming Capacity (FC) 7.9±0.5-15.5±1.2%; Foaming Stability (FS), 87.7±1.5-98.4±2.3%; Water absorption capacity (WAC), 200.0±1.0-240.5±2.3%; Oil Absorption Capacity (OAC), 127.8±4.0-172.3±1.0%; Emulsion Capacity (EC), 50.0±2.0-95.0±1.0mgL^{-1}; Emulsion Stability (ES), 13.0±0.00-43.5±1.0mLg^{-1}; Least Gelation Concentration (LGC), 12.0±0.0-16.0±0.0% w/v; Bulk Density (BD), 531.2±0.1-586.8±0.5gL^{-1}. The protein solubility studies of the flours were found to have minimum solubility at pH range of 4.2-5.5 which correspond to iso-electric point while only SRBF showed minimum solubility of two different PH of 5.0 and 9.2 indicating that two different isolates might be recovered from the sample. FC and FS of the flours increased as the concentration of flour solution increased. There was improvement in LGC with the increase in flour concentration.

Key words: Functional properties, legume seed flours, concentration effect, SR BF, LGC, KSGF

INTRODUCTION

In Africa and the rest of the developing world, where malnutrition due to inadequate protein in nutrition is a prevalent problem there is an urgent need to explore the utilization of plant proteins in the formulation of new food products or in conventional food (Khalid *et al*., 2003). This is predicated on the fact that animal protein such as the meat, milk and eggs are expensive and relatively difficult to acquire (Chel *et al*., 2002). Legumes are leading candidates in this regard since they contain more protein than almost any other plant product. Many of the legumes have protein contents between 20 and 40% and a few ranges between 40 and 60% (Aykroyd and Doughty, 1964).

In addition to providing essential amino acids, seed proteins should also possess the essential requisite functional properties for their successful utilization in various food products. These functional properties are intrinsic physio-chemical characteristics which affect the behaviour of properties in food systems during processing, manufacturing, storage and preparation. Critical functional properties necessary in protein ingredients include gelation which is an important function of proteins in food systems. Surfactant properties are also vital in food systems and functionality. These properties include emulsion capacity, activities and stability. It also includes foam capacity and stability. Other paramount functionalities are proteins solubility, water and fat absorption capacity organoleptic properties and bulk density (Dua *et al*., 1996).

Our research effort has been directed at a systematic study of the chemical composition, nutritional assessment and physicochemical characteristics of some Nigerian under-utilized legume seeds (Aremu *et al*., 2005, 2006 a,b). In continuation of our studies, we have chosen to consider the functional properties of flours derived from two varieties of bambara groundnut (*Vigna subterranean*) kersting's groundnut (*Kerstingiella geocarpa*) two different types of rear cowpea (*Vigna unguiculata*) and scarlet runner beans (*Phaseolus coccineus*) and the influence of flour concentration on them in order to obtain information on the potentiality of the seed flour as a functional ingredient in food system.

MATERIALS AND METHODS

Collection and preparation of sample: Bambara groundnut varieties and Kersting's groundnut were purchased from Nasarawa Market in Nasarawa State, Nigeria while rear cowpea varieties and scarlet runner beans were obtained directly from the farmers in Ogaruku

Corresponding Author: M.O. Aremu, Department of Chemistry, Nasarawa State University, P.M.B. 1022, Keffi, Nigeria

Local Government of Nasarawa State during the harvesting period in December, 2005. The legume seeds were screened to eliminate the bad ones. Cleaned seeds were soaked in distilled water at 35±2°C for 12h after which they were manually dehulled. The dehulled seeds were dried in an air-oven at 40°C and dry-milled into flours. The flours were stored in polythene bags and kept in a refrigerator at about 4°C prior use. The samples were identified as cream coat Bambara Groundnut Flour ($BBGF^1$); red coat Bambara Groundnut Flour ($BBGF^2$); Kersting's Groundnut Flour (KSGF); moderate size Rear Cowpea Flour ($RCPF^1$); small size Rear Cowpea Flour ($RCPF^2$) and scarlet runner beans flour (SRBF). All chemicals used were of analytical (Analar) grade.

Protein solubility: pH dependent proteinsolubility was studied using the method of Aknda (1989) 1.0 g of the flour was dissolved in 10 cm^3 1MNaOH, followed by adjustment to desire pH using IMHCl. The solution was then centrifuged for 15 min at 3500 rpm before the protein content of the supernatural was determined by the micro-kjeldahl method (Pearson, 1976). The percentage nitrogen was converted to crude protein multiplying the percentage by 6.25.

Foaming properties: The method of Coffman and Garcia (1977) was used for the determination of the foaming capacity and stability of legume flours. One gram of legume flour was dispersed in 50 mL distilled water. The resulting solution was vigorously whipped for 3 min in a Kenwood blender and then poured into a 100 mL graduated cylinder. Volumes were recorded before and after whipping and the percentage volume increase calculated according to the following equation:

$$\%\text{ Volume increase} = \frac{\text{Vol. after - Vol. before}}{\text{Vol. before 1}} \times 100$$

Foaming stability was determined as the volume of foam that remained after 8h expressed as a percentage of the initial foam volume. Effect of flour concentration on foaming properties were evaluated by whipping 2, 4, 6, 8 and 10% (w/v) slurries as described above.

Water and oil absorption capacity: The method of Beuchat (1977) procedure was used for water and oil absorption capacity determination. One gram of flour was added, mixed with 10 mL distilled water (density gcm^{-3}) or oil (Executive chef vegetable oil with specific gravity of 0.989 mL^{-1}) in a mixer and kept at room temperature for 30min. It was later centrifuged for 30 min and the supernatant was noted in a 10 mL graduated cylinder. The excess absorbed by the flour was expressed as the percentage of water or oil bound by 100 g sample. Studies were conducted to investigate the effect of flour concentration using 2, 4, 6, 8, 10% (w/v) slurries as described above.

Emulsifying properties: Emulsion capacity ad stability were prepared by using Beuchat's (1977) procedure. One gram of sample was blended in a Kenwood major blender with 50 mL distilled water for 30 sec. At maximum speed. Executive chef oil was added in 5 mL portions with continued blending. A drop in consistency was considered to be the point at which oil addition was discontinued. The emulsion so prepared was then allowed to stand in a graduated cylinder; and the volume of water separated after 24 h was recorded as emulsion stability. Studies were conducted in triplicate.

Gelation properties: Gelation properties of the sample flours were determined by employing the method of Coffman and Garcia (1977) with slight modifications. Flour suspensions of 2-12% (w/v) were prepared in distilled water. The test tubes containing these suspensions were heated for 1h in boiling water, followed by rapid cooling under running tap water. The test tubes were then cooled for 2h at 40°C. The least gelation concentration was taken as the concentration when the sample from the inverted test tube did not fall or slip.

Studies in the effect of flour concentration on gelation property were conducted by preparing 2, 4, 6, 8 and 10% w/v) slurries and least gelation concentration was evaluated as described earlier.

Bulk density: The bulk density of the seed flours was determined using the procedure of Chou and Morr (1979) as modified by Akapapunam and Markakis (1981), Narayana and Narasinga Rao (1984).

RESULTS AND DISCUSSION

Foaming properties: The foaming capacity and stability of the legume seed flours are presented in Table 1. Foaming capacities which ranged from 7.9±0.5% in $BBGF^1$ to 28.1±0.5 in SRBF are comparable favourably with benniseed (18.0%), pearl millet (11.3%) and guinea (9.0%) as reported by Oshodi *et al.* (1999) and bilphia sapida pulp (26.62%) and seed flour (8.2%) reported by Akintayo *et al.* (2002) and fluted pumpkin seed flour (10.8%) (Fagbemi and Oshodi, 1991). However, the values reported in the present study for all the legume seed flours are lower than those of soy flour 970%) or sunflower flour (230%) reported by Lin *et al*. (1974) great Northern bean flour (32%) (Sathe and Salunkhe, 1981) varieties of African yam been (54.0-55.0%) (Adeyeye *et al*., 1994) and oil seed flours 940-50%0 (Olaofe *et al*., 1994). The foaming stabilities after 8h ranged between 87.7±1.5% in RCPF[2] to 98.4±2.3% in BBGF[2]. This suggest that some of the studied samples may be attractive for products like cakes or whipping topping where foaming is important (Kinsella, 1979).

Water and oil absorption capacity: Table 1 also presents water and fat absorption capacity. The ranged values of Water Absorption Capacity (WAC) from 200.0±1.9% in BBGF[1] to 240.5±2.3 in SRBF. These values are comparatively higher than the value of soybean flour (130%) reported by Lin *et al*. (1974), African yam bean colour varieties flour (118-179%) (Oshodi *et al*., 1997) various lina bean flours (130-140%) (Oshodi and Adelodun, 1993) triticumdurum flour (140.63%) (Adeyeye and Aye, 2005), oil seed flour (70-120%) (Olaofe *et al*., 1994) and telfairia occidentals (90.2%) (Akintayo, 1997). The high water absorptivity reported in the present study suggested that varieties of bambara groundnut, kersting's groundnut, rear cowpea and scarlet runner beans may be used in the formulation of some foods such as sausage, doughs, processed cheese, soups, baked products (Olaof *et al*., 1998; Oshodi and Ekperigin, 1989).

The highest Oil Absorption Capacity (OAC) was found in KSGF (172.3±1.0%) and the lowest in RCPF2 (127.8±40%). The values are in close agreement with mucuna bean (160%), jack bean (170.0%) and bambara groundnut (130.0%) reported by Adebowale and Lawal (2004); varieties of African yam bean flour (93.33-145%) (Oshodi *et al*., 1997)bilphia sapida pulp and seeds flour (125.0/131.6%) (Akintayo *et al*., 2002) melon seed (122%) (Olaofe *et al*., 1994) and *P. angularis* 9147%) and *P. calcaratus* (128.7%) (Chau and Cheung, 1998). Oil absorption capacity is importance since oil acts as flavour retainer and increases the mouth feel of foods (Kinsella, 1976). It has been reported that variations in the presence of non-polar side chains, which might bind the hydrocarbon side chains of oil among the flours, explain differences in the oil binding [a]Each value represents mean of three determinations±standard deviation capacity of the flours (Adebowale and Lawal, 2004). However, the flours in the present study are potentially useful in structural interaction in food especially in flavour retention, improvement of palatability and extension of shelf life particularly in bakery or meat products where fat absorption is desired.

Emulsifying properties: Emulsion Capacity (EC) and Stability (ES) are shown in Table 1. The values of EC ranged from 50.0±2.0 mLg^{-1} in SRBF to 95.0±1.0 mL g^{-1} in BBGF[1]. These values are comparable to benniseed 63.0% and pearl millet 89.0% reported by Oshodi *et al*. (1999) Pigean pea (49.4%) (Oshodi and Ekperigin, 1989) and varieties of mushroom samples (76.0-87.0 mL g^{-1}) (Adeyeye *et al*., 2005). Howerener, the values are much higher than soybean flour (18.00%) and wheat flour (11.0%) (Lin *et al*., 1974) ated (925.6±0.8%) (Olaofe *et al*., 1998) flours may be most useful as an additive for the stabilization of fat emulsions in the production of sausage, soup and cake (Altschul and Wikks, 1985). Table 1 shows further that after 24 h, the emulsion stability which is the volume of water separated ranging from 13.0±0.0 mL g^{-1} in BBGF[1] to 43.5±1.0 mL g^{-1} in SRBF. All the flours showed comparatively high values and over a period of 24 h all produce good and stable emulsion stability. The decrease in E.C with time might be due to increased contact leading to coalescence reducing the stability (Parker, 1987).

Gelation properties: The Least Gelation Concentration (LGC) which is defined as the lowest protein concentration at which gel remained in the inverted tube was used as an index of gelation capacity. The lower the LGC, the better the gelating ability of the protein ingredient (Akintayo *et al*., 1999). LGC in the present study ranged from 12.0±0.0% w/v) in BBGF[1] to 16.0±0.0% (w/v) in RCPF[1] (Table 1). Variation in the values obtained might be linked to the relative ratio of different constituents-proteins, carbohydrates and lipids as suggested by Sathe *et al.* (1982) that the interaction between such components may affect functional properties. The values for BBGF[2], KSGF and SRBF (14.0% w/v) is similar to lupin seed flour 14.0%w/v) (Sathe *et al*., 1982) and pumpkin seed (14.0%) (Olaofe *et al*., 1994)

Table 1: Some functional properties of legume seed flours[a]

Property	BBGF[1]	BBGF[2]	KSGF	RCPF[1]	RCPF[2]	SRBF
FC (%)	7.9±0.5	9.9±1.0	13.2±2.1	14.6±3.0	15.5±1.2	28.1±0.5
FS (%)	98.1±3.4	98.4±2.3	91.2±1.0	89.6±2.4	87.7±1.5	89.1±2.3
WAC(%)	200.0±1.0	240.1±2.5	230.5±3.4	240.1±1.2	200.6±1.3	240.5±2.3
OAC(%)	140.0±2.0	140.2±4.0	172.3±1.0	160.0±1.0	127.8±4.0	140.0±5.0
EC(mL g^{-1})	95.0±1.0	65.0±0.0	60.3±6.0	55.0±1.0	55.0±1	50.0±2.0
ES(mL g^{-1})	13.0±0.0	30.0±1.0	35.0±2.0	31.0±2.1	26.0±1.0	43.5±1.0
LGC(%w/v)	12.0±0.0	14.0±0.0	14.0±0.0	16.0±0.0	13.3±0.2	14.0±0.2
BD(gL^{-1})	516.8±0.1	586±0.5	563.1±0.8	549.8±1.0	531.2±0.1	16.8±0.3

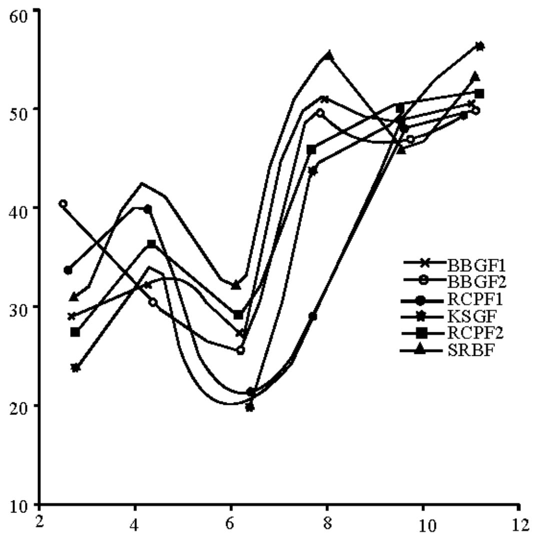

Fig. 1: Variation of protein solubillity of legume seed flours

BRGF[1] = Cream coat Bambara Ground Flour
BRGF[2] = Red coat Bambara Ground Flour
KSGF = Kersting' s Ground Flour
RCPF[1] = Rear Cowpea Flour (moderate size)
RCPF[2] = Rear Cowpea Flour (small size)
SRBF = Scarlet Runner Bean Flour

while that of RCPF[1] (16.0% w/v) is comparable to [quinoa]flour (16.0% w/v) and Adenopus breviflorus benth flour (16.0% w/v) (Oshodi, 1992). The ability of protein to form gels and provide a structural matric for holding water, flavours sugars and food ingredients is useful in food applications and in new product development, thereby providing an added dimension to protein functionality (Oshodi *et al.*, 1997; Sathe *et al.*, 1982). The low gelation concentration observed may be an asset in the use of these flours for the formulation of curd or as an additive to other gel-forming materials in food products.

Bulk density: Bulk density with range values of 531.2±0.1 g L^{-1} in RCPF[2] to 586.8±0.5 g L^{-1} in BBGF[2] are depicted in Table 1. These values are higher than the values reported for various samples of extrusion texturized soya products with varied protein and soluble sugar contents (238.2-446.0g L^{-1}) (Cherry, 1981)and various processed defatted fluted pumpkin seed flours (180-380 g L^{-1}) (Fagbemi *et al.*, 2006).

Protein solubility: The results for variation of protein solubility with pH are presented in Fig. 1 which indicates minimum protein solubilities at pH range of 4.2 in BBGF[2] to 5.5 in KSGF and these correspond to their iso-electric points. SRBF showed minimum protein solubility at two

Table 2: Effect of flour concentration on foaming capacity of flours[a,b]

Sample	Concentration (%w/v) 2	4	6	8	10
BBGF[1]	20.8±.2	35.4±3.4	33.1±2.0	37.7±3.4	35.5±2.0
BBGF[2]	21.3±1.5	35.4±3.4	26.3±2.4	28.8±1.0	31.2±1.6
KSPF	32.4±2.1	51.4±.4	39.2±1.5	40.7±2.6	44.6±6.1
RCPF[1]	48.6±2.4	11.4±4.1	58.3±1.1	61.7±5.1	66.1±3.2
RCPF[2]	5.9±2.3	64.4±3.2	21.3±2.7	23.8±1.6	26.2±1.4
SRBF	57.1±3.0	64.4±3.2	67.4±6.4	69.2±2.6	71.5±1.1

[a]Each value represents mean of three determinations±standard deviation
[b]Values are expressed as%

Table 3: Effect of flour concentration on foaming stability of flours[a,b]

Sample	Concentration (% w/v) 2	4	6	8	10
BBGF[1]	82.4±1.0	83.7±2.3	84.6±5.1	90.9±2.0	92.1±1.5
BBGF[2]	85.2±2.3	87.0±1.2	88.4±1.3	89.6±3.1	90.2±1.0
KSGF	77.8±3.2	81.7±1.3	82.8±3.4	83.0±2.5	84.6±1.4
RCPF[1]	74.0±1.2	78.2±3.0	81.0±1.8	84.2±1.3	85.5±0.5
RCPF[2]	81.4±1.2	85.1±6.3	86.7±5.0	87.8±4.4	90.2±2.1
SRBF	74.2±2.0	76.1±3.4	78.3v3.0	81.5±4.5	86.1±6.2

[a]Each value represents mean of three determinations±standard deviation
[b]Values are expressed as%

different pH of 5.0 and 9.2. This observation is similar to that of Adenopus breviflorus benth and soybean flour concentrate (Oshodi, 1992; Padilla *et al.*, 1996). These results suggest that there is more extractions of soluble proteins at alkaline h as been reported by Ma and Harwalkar (1984) or there is denaturation pHwhich increases proteins solubility (Fagbemi *et al.*, 2006). The solubility in both acid and alkali indicates that it may not be useful in formulating carbonated beverages (Olaofe *et al.*, 1998) and very low acid foods such as meat and milk-analogue (Pomeranz and Clifton, 1981). Generally, solubility increased as the pH increased from 1.0 to 3.0 and then decreasing until it reached minimum between pH 4.2 to 5.5, followed by progressive increase in solubility as the pH increased except BBGF[2] which started decreasing right from pH 1. At pH 7, which is neutral pH, maximum solubility of 52.5 mg cm^3 was observed in SRBF while KSGF had the least value of 20.0 mg cm^{-3}. Similar results have been reported for Triticum durum whole meal flour (Adeyeye and Aye, 2005) mung bean (Thompson, 1977) winged bean (Okezie and Bello, 1988), flours of different phaseolus species such as black gram (Sathe and Salunkhe, 1981) and oil seeds (Olaofe *et al.*, 1994).

Flour concentration effect of foaming and gelation properties Effect of flour concentration on foaming capacity is shown in Table 2. A progressive increase in foaming capacity was observed in all the sample flours as the concentration of flour in solution increased. The highest FC was recorded in SRBF (71.5±1.1%) when the concentration was 10% w/v while the least was recorded in BBGF[1] (20.8±1.2) at 2.0w/v. Foaming Stability (FS) of all the flours increased with concentration of flour in solution

Table 4: Effect of flour concentration on least gelation concentration[a]

Sample	Concentration (% w/v) 2	4	6	8	10
BBGF[1]	12	10	10	10	8
BBGF[2]	12	10	10	8	6
KSGF	12	12	10	10	8
RCPF[1]	16	14	12	10	8
RCPF[2]	12	10	10	8	8
SRBF	14	12	10	10	8

[a]Values are expressed as% w/v

(Table 3) and the highest and lowest FS in all the samples were recorded in BBGF[1] at 10%w/v and RCPF[1] at 2% respectively. Increase in protein concentration facilitated enhanced protein-protein interaction at the air-water interface and this promoted formation of a highly viscolastic multiplayer film that offers resistance to coalescence of bubbles. This development enhanced foaming stability (Adebowala and Lawal, 2003; Cherry and Mcwatters, 1981).

Effect of flour concentration on gelation capacity of flours is presented in Table 4. Generally increase in flour concentration from 2-10% w/v improved the gelation capacity of legume flours. Turgeon and Beaulieu (2001), Adebowale and Lawal (2004) have also reported improvement on protein gel texture using carbohydrates. Improvement in gelation capacity following the increase in concentration of sample flour is because of decrease in thermodynamic affinity of proteins for the aqueous solution, which increased the interaction between proteins.

CONCLUSION

All the legume seed flours were found to possess good foaming capacity and stability; emulsion capacity and stability, water and oil absorption capacities and gelation property. The solubilities of the flours are high enough, making them potentially useful in some food formulations. However, more extraction of soluble proteins at alkaline pH are likely possible in scarlet runner beans which showed minimum protein solubility at two different pH of 5.0 and 9.2. There was a progressive increase in foaming capacity and stability as the concentration of flour solution increased while gelation property was also influenced positively with additional sample flour.

FC = Foaming Capacity; FS = Foaming Stability; WAC = Water Absorption Capacity; FAC = Fat Absorption Capacity; EC = Emulsion Capacity; ES = Emulsion Stability; LGC = Least Gelation Concentration; BD = Bulk Density; BBGF[1] = Bambara Groundnut Flour (cream coat); BBGF[2] = Bambara Groundnut Flour (red coat); Kersting's Groundnut flour; RCPF[1] = Rear Cowpea Flour (moderate size); RCPF[2] = Rear Cowpea Flour (small size) and Scarlet Runner Bean Flour.

REFERENCES

Adebowale, K.O. and O. S. Lawal, 2003. Foaming gelation, electrophoretic characteristics of mucuna bean. Food Chem., 83: 237-246.

Adebowale, K.O. and O.S. Lawal, 2004, Comparative study of the functional properties of bambara groundnut, jackbean and mucuna bean flours. Food Res. Int., 37: 355-364.

Adeyeye, E.I. and P.A. Aye, 2005. Chemical composition and the effect of salts on th food properties of wheat flour. Pak. J. Nut., 4: 187-196.

Adeyeye, E.I., A.A. Oshodi and K.O. Ipinmoroti, 1994. Functional properties of some varieties of African yam bean flour. Int. J. Food Sci. Nut., 45: 829-836.

Adeyeye, E.I., S.S. Asaolu, O. Olaofe and F.O.Abulude, 2005. Effects of some salt on water absorption, least gelation capacities and oil emulsion stability of edible mushrooms. Adva. Food Sci., 27: 56-60.

Akande, A.O., 1989. Some nutritional and physico-chemical studies in Bilphia sapida. Bio-Science Res. Communications 1: 131-138.

Akintayo, E.T, A.A. Oshodi and K.O. Esuoso, 1999. Effects of NaCl, ionic strength and pH on the foaming and gelation of pigeon pea (*Cajanins cajan*) protein concentrates, Food Chem., 66: 51-56.

Akintayo, E.T., 1997. Chemical composition and physico-chemical properties of fluted pumpkin (*Telfairia occidentalis*) seed and seed oils. Rivista Italiana sostanze Grasse, 74: 13-16.

Akintayo, E.T., E.A. Adebayo and L.A. Arogundade, 2002. Chemical composition, physico-chemical and functional properties of akaa pulp and seed flours. Food Chem., 77: 333-336.

Akpa Punam, M.A and D. Markakis, 1981. Physico-chemical and nutritional aspects of cowpea flour. J. Food Sci., 46: 972-973.

Altschul, A.M. and H.L. Wikks, 1985. New protein foods. Food Science and Technical Academic Press. Orlando Florida, pp: 45.

Aremu, M.O., O. Olaofe and E.T. Akintayo 2006b. Compositional evaluation of cowpea (*Vigna unguiculata*) varieties and scarlet runner beans (*Phaseolus coccineus*) varieties flour J. Food Agric. Environ., 4: 2.

Aremu, M.O., O. Olaofe and E.T. Akintayo, 2005. Nutritional quality assessment of the whole and dehulled samples of some Nigerian under-utilized legume seeds. Bull. Pure and Applied Sci., 24: 47-52.

Aremu, M.O., O. Olaofe and E.T. Akintayo, 2006. A comparative study on the chemical composition of some Nigerian under-utilized legume flours. Pak. J. Nut., 5: 34-38.

Aremu, M.O., O. Olaofe and E.T. Akintayo, 2006a. Chemical composition Physio-chemical characteristics of two varieties of Bambara groundnut (*Vgna subterranea*) flours J. Applied Sci., 4: 6.

Aykroyd, W.R. and J. Doughty, 1964. Legumes in human Nutrition. Food and agricultural organisation nutritional study, FAO., pp:138-152.

Beuchat, L.R., 1977. Functional and electrophoretic characteristics of succinylated peanut flour protein. J. Agric. Food Chem., 25: 258-261.

Chau, C.F. and P.K. Cheung, 1998. Functional properties of flours from three Chinese indigenous legume seeds. Food Chem., 61: 429-433.

Chel-Guerrero, V. and D. Perez -Flores, Bentacur-Ancona and Davilla-Ortiz, 2002. functional properties of flours and protein isolates from phaseolus lunatusand canavalia ensiformis seeds. J. Agric. Food Chem., 50: 584-591.

Cherry, J.P. and K.H. Mcwatters, 1981. Whippability and Aeration in Protein Functionality in Foods. In: J.P. Cherry (Ed.), ACS symposium series. Washington D.C. Am. Chem. Soc., 101: 147-149.

Cherry, J.P., 1981. Protein functionality in foods, ACS symposium series. Am. Chem. Soc., Washington D.C., pp: 51-87.

Chou, D. and C.U. Movr, 1979. Protein-water interactions and functional properties. Am. Oil Chem. Soc., 56: 53-58.

Coffman, C.W. and V.V. Garcia, 1977. Functional properties and amino acid content of a protein solate from mung bean flour. J. Food Tech., 12: 473-484.

Dua, S.A., Mahajan and A. Mahajan, 1996. Improvement in functional properties of rape seed (Brassica Campestris Var toria) preparations by chemical modification. J. Agric. Food Chem., 44: 706-710.

Fagbemi, T.N. and A.A. Oshodi, 1991. Chemical composition and functional properties of full fat fluted pumpkin seed flour. Nig. Food J., 9: 20-32.

Fagbemi, T.N., A.A. Oshodi and K.O. Ipinmoroti, 2006. Effects of processing in the functional properties of full fat and defatted fluted pumpkin seed flours. J. Food Tech., 4: 70-79.

Khalid, E.K, E.E. Babiker and A. H. Tinay, 2003. Solubility and functional properties of sesame seed properties as inflenced by pH and/or salt concentration. Food Chem., 82: 361-366.

Kinsella T.E.,1976. Functional properties of protein foods. Crit. Rev. Sci. Mtr., 1: 219-229.

Kinsella, J.E., 1979. Functional properties of soy proteins. J. Am. Oil Chemists Soc., 56: 242-258.

Lin, M.J.Y., E.S. Humbert and F.W. Soziliki, 1974. Certain functional properties of sunflower meal products. J. Food Sci., 39: 368-370.

Ma, C.T. and V.R. Harwalkev, 1984. Chemical characterization and functionality assessment of oat protein traifirine. J. Agric. Food Chem., 32: 44-149.

Narayana, K. and M.S. Narasinga Rao, 1984, Effect of partial proteolyses on the functional properties of winged bean (*Phosphorcapus tetragonolobus*) flour. J. Food Sci., 49: 944-947.

Okezie, B.O. and A.B. Bello, 1988. Physico-chemical and functional properties of winged bean flour and isolate compared with soy isolate. J. Food Sci., 53: 450-454.

Olaofe, O., F.O. Adeyemi and G.O. Adediran, 1994. Amino acid and mineral composition and functional properties of some oil seeds. J. Agric. Food Chem., 42: 878-881.

Olaofe, O., L.A. Arogundade, E.I. Adeyeye and O.M. Falusi, 1998. Composition and food properties of the variegated grasshopper. Trop. Sci., 38: 233-237.

Oshodi, A.A. and M.M. Ekperigin, 1989. Functional properties of pigeon pea flour. Food Chem., 34: 187-191.

Oshodi, A.A., H.N. Ogungbenle and M.O. Oladimeji, 1999. Chemical comprarits, nutritionally valuable minerals and functional properties of benniseed, pearl millet and quinoa flours. Int. J. Food Sci. Nut., 50: 325-331.

Oshodi, A.A. and M.O.A. Adeladun, 1993. Proximate composition, some valuable minerals and functional properties of three varieties of liman bean flour. Int. J. Food Sci. Nut., 43: 181-185.

Oshodi, A.A., 1992. Proximato compration, Nutritional valuable minerals and functional properties of Adenopus breriflorus benth seed flour and protein concentrate. Food Chem., 45: 79-83.

Oshodi, A.A., K.O. Ipinmoroti and E.I. Adeyeye, 1997. Functional properties of some varieties of African yam bean flour. Int. J. Food Sci., Nut., 48: 243-250.

Padilla, F.C., M.T. Alvarez and M.J. Alfaro, 1996. Functional properties of barinas nut flour compared to those of soybean. Food Chem., 57: 191-196.

Parker, N.S., 1987. Properties and functions of stabilizing agents in foods emulsions. Crit. Rev. Food Sci., Nato., 25: 112-120.

Pearson, D., 1976 Chemical Analysis of Foods. (7th Edn.), London Church Hill Livingstone, pp: 37-38.

Pomeranz, Y. and D. Clifton, 1981. In: E.E. Melon (Ed.), Food Analysis Theory and Practices. Westport, C. T. Avi Publishing Company.

Sathe, S.K and D.K. Salunkhe, 1981. Functional properties of the great Northern beans (*Phasesolus vulgaris* L.) proteins, emulsion, foaming viscosity and gelation properties. J. Food Sci., 46: 71-76.

Sathe, S.K, S.S. Desgpande and D.K. Salunkhe, 1982. Functional properties of lupin seed (*Lupirinus mutabilis*) proteins and protein concentrates. J. Food Sci., 47: 491-497.

Thompson, L.U., 1977. Preparation and evaluation of mung bean proteins isolates. J. Food Sci., 42: 2002.

Turgeon, S.L. and M. Beaulieu, 2001. Improvement and modification of whey protein gel texture, using poly-saccharides. Food Hydrocolloids, 15: 583-591.