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Soyabean meal versus soyabean protein isolate: A comparative study of the nutritive and functional attributes

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Abstract

Soya bean meal (SBM) and soya bean protein isolate (SPI) were both prepared from soya bean seeds. The two samples were comparatively characterized with respect to their proximate constituents, energy values, mineral constituents, amino acid profile and functional properties. The crude protein (CP), ether extract (EE), crude fibre (CF), ash, nitrogen-free extract (NFE) and gross energy of the SMB averaged 42.0, 1.2, 5.6, 5.9, 31.9 g/100 g DM and 486.2 kcal/100 g, respectively. The corresponding values for the SPI were 85.8, 0.6, 0.2, 1.0, 4.4 g/100 g DM and 512.4 kcal/100 g, respectively. One of the major nutritive minerals analysed, potassium was the most abundant in SBM followed by phosphorus and calcium while sodium was the least one. Among the trace minerals, iron had the highest concentration and manganese the least one. A similar trend was found in SPI except that phosphorus was the most abundant among the major minerals. The amino acid profile of the SMB and SPI showed a favourable balance of both the essential and the non-essential amino acids. For example in SBM, values for lysine, valine, phenylalanine, aspartic acid, glutamic acid, proline and serine were 25.6, 20.2, 21.0, 48.0, 74.5, 20.9 and 21.1 g/16 g N while the corresponding values for SPI (which were higher) were 50.0, 42.5, 42.2, 43.4, 98.4, 160.8, 45.4 and 43.0 g/16 g N, respectively. From the scores, the 1st limiting amino acid was methionine for both SMB and SPI at 41.7 and 47.2%, respectively. The SBM had fat absorption capacity (FAC), water absorption capacity (WAC), emulsion capacity (EC) and emulsion stability (ES) of 200, 310, 45.7 and 46.8% while the SPI had 1000, 1000, 46.3 and 0%, respectively. High variations were found in FAC and WAC which was indicated by high coefficient of variation (CV) of 94.3 and 74.8%, respectively. The foaming capacity (FC) and foaming stability (FS) of SMB and SPI were 63, 108% and 3.3, 120%, respectively. The two samples had varying solubilities with change in pH. The proteins generally had multiple maxima and minima in their solubilities. Isolation of protein from soya bean to get SPI, generally brought about increased nutritive and functional attributes when compared with soya bean meal (SBM).

Key words: Soya bean meal (SBM) and soya bean protein isolate (SPI), proximate constituents, energy values, mineral constituents, amino acid profile and functional properties.

Introduction

Protein is one of the most valuable nutrients in foods and its availability has been the major concern of food scientist in developing countries. It is widely appreciated that the developing countries of the world, including Nigeria, do not produce enough food and of the right quality to meet their daily requirements. Protein foods are particularly in short supply especially with regards to protein from animal source in developing countries. Consequently, the larger segment of the population in developing countries gets most calories from cereal grains, starchy roots and tubers [7]. Only 16% of the plant proteins available for consumption come from pulses and nuts, 83% are derived from starchy foods [1, 18]. Protein from animal sources contributed less than 2% of total caloric output for the whole nation and the annual rate of increase is only 4%. Thus, the overall protein situation is that the present rate of production falls below requirements. This general protein shortage in Nigeria for example, with an ever growing population calls for immediate action if hunger, famine and malnutrition on a large-scale are to be prevented in the near future.

Soya bean (*Glycine max*) is a tropical crop with wide spread use as food and animal feed. They are mainly planted for the food value of their fruits such as the husk, pulp and their seeds which have found numerous applications in most traditional African foods and spices [8]. While there is ample literature on the nutrient composition and sensory attributes of this seed [2, 5, 9] there is limited information on the isolation of protein from the meal and the effect on the nutritional composition and physicochemical attributes. The aim of the study was therefore to compare the nutritional composition of the soya bean meal (SBM) and the soya bean protein isolate (SPI) in order to provide useful information that can enhance the utilization of the protein isolate in conventional and novel food products.

Materials and Methods

Sample of raw soya bean was purchased from the local market in Akure, Nigeria. About 2 kg of the seed was dried and milled and divided into two portions, one portion was used to produce the soya bean meal by mechanical extraction of the oil using screw-press while the other portion was used for the production of the protein isolate.

Preparation of protein isolates: The procedure for isolate preparation was as described by Lqari *et al.*[19] with some modifications which involved the use of different extractants as mentioned below. The milled sample was sieved to pass a 0.5 mm mesh and kept in air-tight plastic container in a refrigerator at 4^0C prior to use. The fraction collected (<0.5 mm) referred to as flour was defatted by extracting with n-hexane in a Soxhlet extractor for 9 hours, followed by air-drying in the fume cupboard for 24 hours.

The slurry (1:20, flour to water ratio) at pH 6.37and 28^{o}C was first extracted for 10 min as indicated in Fig. 1. Thereafter, the slurry was stirred for 2 h with a Gallenkamp magnetic stirrer and the pH was adjusted to pH 6.5 with 1 M NaOH or 1 M HCl. Different extractants (ascorbic acid (0.5%) w/v; EDTA + 0.25% ascorbic acid; cystein (0.5%); sodium sulphite (0.25%) and water were added singly. Each extract was centrifuged in a Sorvall RC5C automatic super speed refrigerated centrifuge at 10,000 x g for 30 minutes at 5^{o}C. After centrifugation and recovery of supernatant, three additional extractions were carried out with half of the volume of the initial water. The supernatants were pooled and precipitated at pH 5.0, the isoelectric point (IEP). The precipitate formed was subsequently recovered by centrifugation at 10,000 x g for 15 minutes at 5^{o}C. The precipitate was washed twice with distilled water adjusted to pH 5.0 with HCl and then freeze-dried. The precipitate was neutralized by the addition of 1M NaOH.

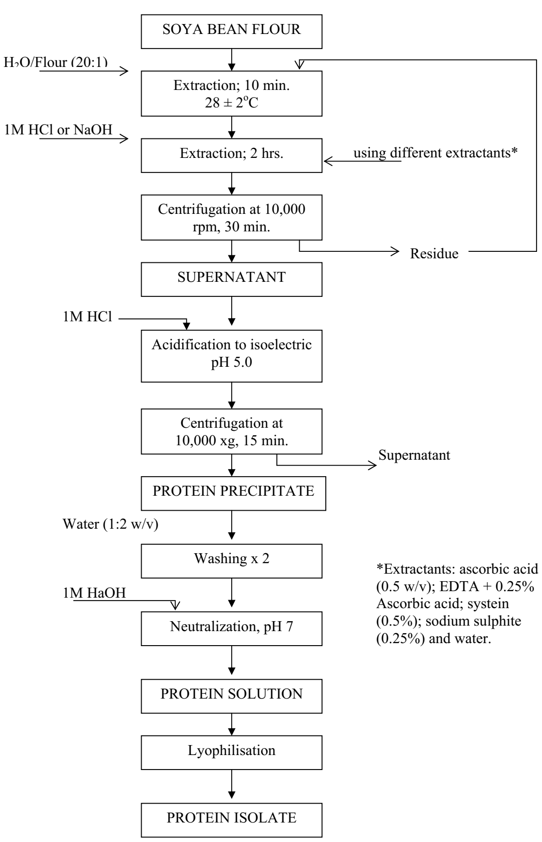

Figure 1. Flow chart for protein isolate extraction.

Chemical and physico-chemical analyses: Proximate analysis of the samples was carried out in triplicates, using the method described by AOAC [10]. Nitrogen was determined by micro-Kjeldahl method [10] and the nitrogen percentage was converted to crude protein by multiplying by 6.25. The gross energy content of the samples was computed from the proximate constituents [21]. The minerals were analysed after dry-ashing at 550^{o}C in a muffle furnace and dissolved in deionized water to make standard solutions. Sodium and potassium were determined by flame photometry, phosphorus was determined by vanado-molybdate method [10] and Ca, Mg Zn, Mn, Fe and Cu were determined using atomic absorption spectrophotometry [28].

Determination of the functional properties: The variation of protein solubilities with pH was determined as described by Oshodi and Aletor [19]. Water absorption capacity (WAC) and fat emulsion stability (FES) were determined by the procedure of Beuchat [11]. The fat absorption capacity (FAC) was determined as described by Sosulki [26]. Similarly, the lowest gelation concentration (LGC), foaming capacity (FC) and foaming stability of the samples were determined using the technique of Coffman and Garcia [12].

Amino acid analysis: The amino acid composition of the samples was determined by hydrolyzing 50–75 mg sample with 5 cm^3 of 6 M HCl in screw-capped glass hydrolysis tube. The tubes and the content were refluxed for 24 hours by placing in a heating block previously heated to 110 ±1^{o}C. The hydrolysate was cooled and quantitatively transferred to a 50 cm^3 flask and diluted to volume with water. After filtration, a 10 cm^3 aliquot of the filtrate was heated in a rotary evaporator (40 EC) to remove excess acid before analysis using HPLC Autosampler (Kontron 460). Methionine was determined as methonine sulphone and cystine as cysteic acid after perfoming acid oxidation while tryptophan was determined chemically by basic hydrolysis [20]. To correct for slight fluctuations in amino acid peaks, DL-amino-n-butyric acid was used as internal standard.

Amino acid score (chemical score): From the amino acid data, the amino scores (AAS) were computed (egg protein as reference)[15] as follows :

$$AAS = \frac{\text{mg of amino acid per g test protein}}{\text{mg of amino acid per g reference protein}} \times 100$$

The chemical score was thereafter established as the % of the most, or 1st limiting amino acid.

Data analysis: All means were derived from triplicate (n = 3) determinations. The coefficients of variation (CV %) between the meal and protein isolate were also computed as described [27].

Results and Discussion

The mean values of the proximate constituents and gross energy of the soya bean meal (SBM) as well as the soya bean protein isolate (SPI) are shown in Table 1. The crude protein ranged from 42.0 g/100 g DM in SBM to 85.8 g/100 g DM in SPI with a coefficient of variation (CV) of 48.5%. The ether extract, crude fibre and ash of the SBM and SPI averaged 1.2, 5.6, 5.9 g/100 g DM and 0.6, 0.2, 1.0 g/100 g DM respectively. The soya bean meal had a higher level of ether extract, crude fibre, ash and NFE than SPI, while the crude protein was higher in SPI. The gross energy of the SBM ranged from 486.2 kcal/100 g in SBM to 512.4 kcal/100 g in SPI. Higher NFE value which is a measure of the carbohydrates

Table 1. Proximate constituents (g/100 g DM) and energy values (kcal/100 g) of soya bean meal and soya bean protein isolate.

Protein source	DM	Crude protein	Ether extract	Crude fibre	Ash	NFE	Gross energy
Soya bean meal	86.6	42.0	1.2	5.6	5.9	31.9	486.2
Soya bean protein isolate	92.0	85.8	0.6	0.2	1.0	4.4	512.4
Mean	89.3	93.9	0.9	2.8	3.5	18.2	499.3
S.D.	3.8	31.0	0.4	3.8	3.5	19.5	18.5
CV (%)	4.3	48.5	44.4	135.7	100	107.1	3.8

Means are for triplicate determinations; NFE nitrogen free extract; S.D. standard deviation; CV coefficient of variation.

in foods was recorded for SBM than SPI. Although the SPI had lower NFE and EE than SBM, the much higher CP of the former generally conferred higher caloric value. The results of NFE and EE on SBM and SPI compared well with those reported for cashew nut seed [7] but were lower than those reported for full fat fluted pumpkin seeds [17]. An observation from the analytical result in this study with regard to the proximate constituents and energy value is the relatively high nutrient density especially the CP and GE in SPI. The ash content of SBM surpass that of SPI which suggests or implies that the dietary value of SBM could be expected to contribute a larger proportion of the mineral requirement in the body than that of SPI.

Of all the nutritionally important major minerals (Table 2), Ca, K and Mg were most abundant in SBM with the values of 0.32, 1.93 and 1.93 g/100 g DM, respectively, while the SPI had 0.15, 0.27 and 0.08 g/100 g DM, respectively. Both samples had identical phosphorus content (0.64 g/100 g DM). Of the trace minerals, Fe was most abundant with values of 198.7 and 137.0 mg/kg in SBM and SPI, respectively, while the lowest values of 19.7 and 14.3 mg/kg were recorded for Cu in SBM and SPI, respectively. Although the mineral contents of SPI were generally low when compared with those of SBM, the values were generally within the range reported for most grain legumes [14, 24] and similar to those reported for vegetables [6]. While grain legumes represent useful sources of desirable minerals, they are usually less biologically available than those from animal origin [22]. The poor bioavailability of minerals from plant sources derives from the anti-nutritional effects of certain inherent anti-metal agents in plants, such as phytates and oxalate, which form chelates particularly with divalent minerals such as Ca, Zn, Mg and Fe, thereby making them less available metabolically [5].

The SBM and SPI varied widely in their amino acid content (Table 3) as manifested in their high CV of 22%. The amino acid contents of the SPI were generally higher than in SBM. Of high nutritional interest is the good balance in lysine with 25.6 g/16 g N in SBM to 50.0 g/16 g N in SPI; isoleucine with 18.8 g/16 g N in SBM to 42.5 g/16 g N in SPI; leucine with 12.2 g/16 g N in SBM to 66.4 g/16 g N in SPI; aspartic acid with 48.0 g/16 g N in SBM to 98.4 g/16 g N in SPI and glutamic acid with 74.5 g/16 g N in SBM to 160.8 g/16 g N in SPI. Though both the essential and non-essential amino acids in SBM were lower than those in SPI, these values were in close agreement with those reported for protein

Table 2. Mineral constituents of soya bean meal and soya bean protein isolate.

	Major (g/100 g)					Trace (mg/kg)			
Protein source	Ca	Na	K	P	Mg	Mn	Fe	Cu	Zn
Soya bean meal	0.32	0.01	1.93	0.64	0.27	28.5	198.7	19.7	49.2
Soya bean protein isolate	0.15	0.07	0.27	0.64	0.08	5.1	137.0	14.3	34.0
Mean	0.2	0.0	1.1	0.64	0.2	16.8	167.9	17.0	41.6
S.D.	0.1	0.0	1.2	0.0	0.1	16.6	43.6	3.8	10.8
CV (%)	50.0	0.0	109.1	0.0	50.0	98.8	26.0	22.4	26.0

S.D. standard deviation; CV coefficient of variation.

Table 3. Amino acid profile (g/16 g N) of soya bean meal and soya bean protein isolate.

	Soya bean meal	Soya bean protein isolate	Mean	S.D.	CV (%)
Lysine	25.6	50.0	37.8	17.3	45.8
Methionine	5.6	3.0	9.3	5.2	55.9
Cystein	6.3	14.0	10.2	5.5	53.9
Met + Cystein	1.9	27.0	14.5	17.8	122.6
Threonine	16.3	33.0	24.7	11.8	47.8
Tryptophan	15.1	11.0	13.1	2.9	22.1
Arginine	10.6	68.0	39.3	40.6	103.3
Isoleucine	18.8	42.5	30.5	16.6	54.2
Leucine	12.2	66.4	39.3	38.3	97.5
Valine	20.2	42.2	31.2	15.6	50.0
Histidine	10.9	22.5	16.7	8.2	49.1
Ph. alanine	21.0	43.4	32.2	15.8	49.1
Glycine	17.8	35.3	26.6	12.4	46.4
Asp. acid	48.0	98.4	73.2	35.6	48.6
Glut. acid	74.5	160.8	117.7	61.0	51.8
Alanine	17.9	35.3	26.6	12.3	46.2
Proline	20.9	45.4	33.2	17.3	52.1
Serine	21.1	43.0	32.1	15.5	48.3

S.D. standard deviation; CV coefficient of variation

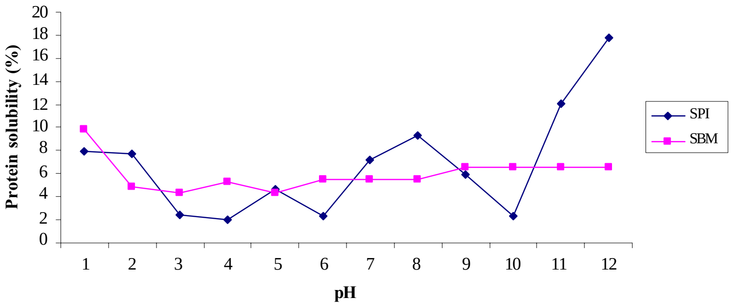

Figure 2. Protein solubilities of soyabean meal (SBM) and soyabean protein isolate (SPI) as a function of pH.

Table 4. Amino acid score (%) of soya bean meal and soya bean protein isolate.

	Soya bean meal	Soya bean protein isolate	Egg ref** (mg/g protein)
Lysine*	96.7	92.3	93
Methionine*	41.7	47.2	32
Cystine*	83.3	90.4	18
Threonine*			
Tryptophan*	79.9	75.2	51
Arginine	199.7	71.1	18
Isoleucine*	119.4	129.6	61
Leucine*	79.9	88.2	56
Valine*	92.7	93.0	83
Histidine*	63.3	64.3	76
Ph Alanine*	108.1	109.0	24
Glycine	98.0	99.0	51
Asp. acid			
Alanine			
Proline			
Serine			
Chemical score	41.7	47.2	
1st Limiting amino acid	Met	Met	
2nd Limiting amino acid	Valine 63.3	Valine 64.3	

**FAO/WHO/UNO[15] *Essential amino acid.

concentrates [3] and surpassed those reported for fish[28].

Amino acid scores of the SBM and SPI are shown in Table 4. SBM had the higher score of 199.7% for tryptophan and least score of 41.7% for methionine, SPI had the higher score of 129.6 for arginine and least score of 47.2 for methionine. The results agreed with those reported for some legume seed proteins and oil seeds [13, 25] that plant proteins are limited by sulphur containing amino acids. The range of chemical scores of 41.7 to 47.2% were similar to those reported for breadnut, cashew nut and fluted pumpkin seed flour [16]. It was clear from the samples that S-amino acids and valine were the first and second limiting amino acids, respectively. This therefore implies that any dietary formulation involving these protein feed/food resources would be mindful of the dietary supply of these amino acids.

Table 5 shows the mean value (%) of fat absorption, water absorption, emulsion capacity and emulsion stability of the SBM and SPI. Fat absorption varied from 200.0 in SBM to 1000.0% in SPI; water absorption varied from 310.0 in SBM to 1000.0 in SPI while no emulsion stability was observed in SPI. Table 6 presents the foaming capacity, foaming stability and least gelation concentration of the SBM and SPI. Foaming capacity varied from 3.3 ± 1.5 in SPI to 6.3 ± 0.8 in SBM and foaming stability from 108.1 ± 1.1 in SBM to 120 ± 1.3 in SPI with low CV of 7.5%. Least gelation varied from 2 ± 0.1 in SBM to 4 ± 0.3% in SPI with high CV of 46.7%.

The two samples showed variable solubilities, with varying pH ranges in both the acidic and basic regions (Fig. 2) which could be useful in industrial applications. The results indicate that SPI showed greater solubilities in the acidic medium which suggest their usefulness in acidic foods. The solubility data suggest that SBM and SPI may find good uses in the manufacture or preparation of both acidic and alkaline foods such as gravis and mayonnaise.

Table 5. Functional properties of soya bean meal and soya bean protein isolate.

	Fat absorption (%)	Water absorption (%)	Emulsion capacity (%)	Emulsion stability (%)
Soya bean meal	200.0 ± 0.4	31.0 ± 2.9	45.7 ± 0.1	46.8 ± 0.7
Soya bean protein isolate	1000 ± 0.6	1000 ± 0.0	46.3 ± 1.1	-
Mean	600.0	655.0	46.0	23.4
S.D.	565.7	487.9	0.4	33.1
CV %	94.3	74.8	0.9	141.5

S.D. standard deviation; CV coefficient of variation.

Table 6. Foaming capacity, foaming stability and least gelation of soya bean meal and soya bean isolate.

	Foaming capacity (%)	Foaming stability (%)	Least gelation (%)
Soya bean meal	6.3 ± 0.8	108 ± 1.1	2 ± 0.1
Soya bean protein isolate	3.3 ± 1.5	120 ± 1.3	4 ± 0.3
Mean	4.8	114.0	3
S.D.	2.1	8.5	1.4
CV (%)	43.8	7.5	46.7

S.D. standard deviation; CV coefficient of variation.

Conclusions

The results of this study showed that protein isolate could be prepared from soya bean meal with much higher protein and amino acid content as well as higher functional properties. The data on the minerals indicated that some of the nutritionally valuable minerals may have been substantially washed off during the preparation of protein isolate. It was suggested that soya protein isolate (with low fibre) may be a more useful additive or supplement than SBM to enhance the protein or food value of low-nitrogen traditional staples such as flours from cereals and tubers.

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