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Original article

Comparative assessment of antioxidant, nutritional and functional properties of soybean and its by-product *okara*

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Abstract

Soybean is considered as functional food due to various bioactive components present in it. In the present study, antioxidants, nutrient composition and functional properties of *okara* (soybean milk residue) were compared to soybean. The study revealed that *okara* possessed good antioxidant activity, *i.e*., total phenolic content (122.57 mg gallic acid/100 g) and DPPH free radical scavenging activity (41.46 %). It also contained considerable concentrations of protein (24.79 g/100 g) and fat (10.52 g/100 g), although less than those of soybean. The total dietary fibre content of *okara* (58.21 g/100 g) was more than double the dietary fibre of soybean (24.75 g/100 g). Insoluble dietary fibre (46.64 g/100 g) was the major fraction in *okara* and remaining was the soluble dietary fibre. *Okara* had significantly lower phytic acid content (843.33 mg phytic acid per 100 g) and higher *in vitro* protein digestibility (68.26%) than soybean. Among minerals, total calcium (346.93 mg/100 g) and phosphorus (480.17 mg/100 g) were significantly higher in *okara*, while, potassium, iron and zinc contents were also in remarkable amounts. The availability of minerals was maximum in *okara*. In addition, *okara* had significantly higher water absorption (9.47 ml/g) and swelling (9.33 ml/g) capacity, whereas, lower oil absorption capacity (0.26 ml/g) and bulk density (0.21 g/ml) as compared to soybean. Thus, *okara* is a valuable by-product and can be considered as a potential source of value addition for food industry due to its promising antioxidants, nutritional and functional properties.

Key words: Antioxidant, functional properties, nutrient, *okara*, soybean

1. Introduction

Soybean (*Glycine max* L.) has assumed significance in agriculture, because it is one of the main food sources in human and animal nutrition. Soybean and its products mainly impressed people all over the world as a rich and cheap source of high quality protein and fat and considered as an aid in solving world food problems (Anbarasu and Vijayalakshmi, 2007).

Soymilk and *tofu* are the most popular and widely consumed soy foods all over the world. Soymilk, a dairy milk substitute is fast becoming a household food in developing countries as it is easily prepared from mature dry beans. Soymilk generates a large amount of *okara* which is discarded as agro-industrial waste with little market value. For each kg of soybean processed into soymilk, an equal weight of *okara* is produced or even more (Lu *et al*., 2013). Soybean as well as its by-product *okara* represent a rich source of dietary fibre, protein and oil and have excellent functional properties. Furthermore, soy also contains isoflavonoids which have beneficial effects on health like cardiovascular diseases, osteoporosis and lowering of certain hormone-dependent cancers, possibly due to their antioxidative properties and their ability to bind the oestrogen receptor (O' Toole, 1999). *Okara* might be useful as a weight-reducing dietary supplement and might protect the gut environment due to its antioxidant and prebiotic effect (Mateos-Aparicio, 2010).

In recent years, much research is focused on the use of vegetable proteins for the development of new conventional food products. To analyze these new valuable sources of protein as food ingredients, their nutritional and functional properties should be known as they play an important role in the physical behaviour of food or ingredients during processing. The high quality protein fraction is responsible for water and fat binding, emulsifying and foaming properties and antihypertension effects (Silva *et al*., 2006) and these non-nutritional properties influence the production and quality of a determined food. Food industries are focused on finding new raw materials to improve the quality of their products, and for that reason, the functional properties are important to reduce costs. Even though, *okara* is frequently treated as an industrial waste, yet due to its peculiar composition, it could be used in the food industry to confer increased nutritional and functional properties to food products (Villanueva-Suárez *et al*., 2013). Keeping this in view, the present study was aimed to assess the antioxidant, nutritional and functional properties of *okara* and compare it with soybean, a most widely used legume crop worldwide.

2. Materials and Methods

2.1 Procurement of raw material

The grains of soybean variety (PS 1347) were procured in a single lot from the Department of Genetics and Plant Breeding, College of

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Agriculture, Chaudhary Charan Singh Haryana Agricultural University, Hisar, India. The seeds were cleaned and made free of dust, dirt and foreign materials and packed in air tight containers for further analysis.

2.2 Extraction of *okara*

Okara was extracted as per Chinese method. Soybean seeds were soaked overnight, rinsed and ground in a blender by adding water in 1:8 w/v to obtain the soy slurry; the resultant soy slurry was filtered through double layered cheese cloth. When filtration slowed, the remaining liquid was squeezed out by pressing with the hand for 1-2 minutes and the residue, thus obtained called as *okara* was freeze dried, ground to fine powder and stored in air tight polythene sheets for further analysis.

2.3 Antioxidants analysis

2.3.1 Total phenolic content

Total phenolic content in methanolic extract was estimated by calorimetric method according to the method of Singleton and Rossi (1965). One ml aliquot of the sample was diluted with 10 ml of distilled water. Then, 1.5 ml Folin Ciocalteu's reagent (Dissolved 10 g of sodium tungstate and 2.5 g of sodium molybdate in 70 ml of water. Added 5 ml of 85% phosphoric acid and 10 ml of concentrated hydrochloric acid. Reflux for 10 h. Added 15 g of lithium sulfate, 5 ml of water, and 1 drop of bromine. Reflux for 15 min. Cooled to room temperature and brought to 100 ml with water) was added and allowed to incubate at room temperature for 5 min, then 4 ml of 20% (w/v) sodium carbonate was added and adjusted to 25 ml with distilled water, agitated and left to stand for 30 min in dark at room temperature and absorbance of the sample was measured at 765 nm. Quantification was done on the basis of a gallic acid standard curve. The results were expressed as mg gallic acid equivalents (GAE).

2.3.2 DPPH free radical scavenging activity

DPPH free radical scavenging activity was determined by the method of Hatano *et al*. (1988). An aliquot of (0.1 ml) methanolic solution containing 20-100 µg of crude phenolic extract of sample was mixed with 2 ml of methanol and then added to a methanolic solution of DPPH (1 mmol/l, 0.25 ml). The mixture was vortexed for 10 s, left to stand at room temperature for 30 min and then its absorbance was recorded at 517 nm against methanol blank. A control was measured using the same procedure except that methanol was used instead of extracts (at zero min). The per cent of DPPH radical discoloration of the sample was calculated according to the equation (%) discoloration:

$$\text{DPPH RSA } (\%) = A_{control} - A_{sample} \times 100 / A_{control}$$

where, $(A_{control})$ = absorbance for the control

(A_{sample}) = absorbance for the sample

2.4 Nutritional analysis

2.4.1 Proximate composition

The moisture, crude protein, crude fat, ash and crude fibre in the samples were estimated by using standard (AOAC, 2012) method. Crude protein was estimated using micro-kjeldhal method using KEL PLUS Automatic Nitrogen Estimation System. Crude fat was determined by the soxhlet extraction method using Automatic SOCS plus Solvent Extraction System. Crude fibre was estimated by acid and alkaline digestion method using Automatic Fibra plus system. The carbohydrate content was calculated by difference method.

2.4.2 Dietary fibre

Dietary fibre contents were assessed by following the enzymatic method of Furda (1981). The sum of insoluble dietary fibre and soluble dietary fibre contents were calculated for determining total dietary fibre content.

2.4.2.1 Insoluble dietary fibre

Extraction of water-soluble material: The defatted sample (2 g) was dispersed in 200 ml of 0.005 N HCl and boiled for 20 min. The suspension was then cooled down to 60°C; 0.3 g of disodium EDTA was added and then adjusted to pH 5.0-6.5 with 12 ml of phosphate buffer pH 10. The extraction was continued for an additional 40 min at 60°C to ensure the extraction of pectins with minimal degradation.

Starch and protein hydrolysis: Adjusted the pH 6.0-6.5 to bring the solution closer to the pH optimum of amylase and protease. Cooled the suspension to 20-30°C before incubation overnight with 10 mg of bacterial alpha-amylase and 10 mg of bacterial protease. The incubation was accompanied by slow stirring with a magnetic bar.

Isolation of insoluble dietary fibre: The suspension was filtered through a coarse-tarred Gooch filtering crucible containing glass wool and the insoluble residue was washed with a small amount of water. The filtrate was saved for the next step. The insoluble residue was then washed with water, alcohol and acetone before being dried at 70°C in a vacuum oven overnight. The dry residue constituted insoluble dietary fibre.

2.4.2.2 Soluble dietary fibre

The saved filtrate was acidified with a few drops of concentrated hydrochloric acid to pH 2-3; this pH tended to facilitate the rapid precipitation of polysaccharides. Slowly added four volumes of ethanol and left suspension to stand for about 1 h. Filtered the precipitate on a tarred, coarse Gooch crucible containing glass wool, then washed with 75 per cent ethanol, absolute ethanol, and acetone before drying at 70°C in a vacuum oven overnight. The residue was weighed in the crucible to give the soluble dietary fibre content of the original material. The soluble dietary fibre fraction was corrected for ash and for-co-precipitated protein.

2.4.2.3 Total dietary fibre

Total dietary fibre = Insoluble dietary fibre + Soluble dietary fibre

2.4.3 Total minerals

For the estimation of total minerals, the samples were wet acid digested using diacid mixture (HNO_3: $HClO_4$:: 5:1, v/v). The total calcium, potassium, iron and zinc in acid digested samples were determined by Atomic Absorption Spectrophotometer according to the method of Lindsey and Norwell (1969) while phosphorus in acid digested samples was determined colorimetrically at 820 nm by using the method of Chen *et al*. (1956).

$$\text{Minerals (mg/100 g)} = \frac{\text{Reading (conc. µg/ml)} \times \text{volume made}}{\text{Weight of sample (g)} \times 1000} \times 100$$

2.4.4 Mineral availability

Available calcium and zinc were extracted by the method of Kim and Zemel (1986). One gram of finely ground sample was taken in a conical flask and 3 ml distilled water was added to rehydrate it. To this 20 ml of pepsin solution (0.1 % pepsin in 0.1N HCl) was added. The pH was adjusted to 1.5 with dilute HCl. The contents were incubated at 37°C in a shaker-cum-water bath for one hour. After one h, the pH contents were raised to 6.8 with sodium bicarbonate solution. Then 2.5 ml of a suspension containing 0.5 per cent pancreatin in 5 per cent bile was added and the contents were again incubated at 37°C for one hour. Then the contents were taken out and total volume was made to 50 ml with distilled water. The contents were then immediately centrifuged at 5000 x g for 45 min at 5°C. Supernatant was collected and re-centrifuged at 2500 x g for 45 min at 5°C. The supernatant was collected; oven dried, digested in the diacid mixture and proceeded for the estimation of calcium and zinc by the atomic absorption spectrophotometric method.

Available iron was extracted according to the procedure of Rao and Prabhavathi (1978). One gram sample was mixed with 25 ml pepsin HCl (0.5 % pepsin in 0.1N HCl) in a conical flask. The pH of the mixture was adjusted to 1.35 with HCl and incubated at 37°C for 90 min in a water bath-cum-shaker. After incubation, pH of the contents was adjusted to 7.5 with NaOH and again incubated at 37°C in a water bath-cum-shaker for 90 min. Contents of the flasks were centrifuged at 3000 rpm for 45 min and the supernatant was filtered through Whatman No. 42 filter paper. The filtrate was oven dried, digested in the diacid mixture and preceded for the determination of iron by atomic absorption spectrophotometric method.

2.4.5 Phytic acid content

Phytic acid content was determined by the method given by Davies and Reid (1979). To 500 mg sample, 20 ml 0.5 M HNO_3 was added in a conical flask and shaken continuously for 3 h on shaker at room temperature and filtered. Supernatant was used for estimation of phytic acid. To a test tube, 0.5 ml HNO_3 extract was taken and volume was made to 1.4 ml with water. To it, 1 ml ferric ammonium sulphate solution wad added, the contents were thoroughly mixed and placed in boiling water bath for 20 min, immediately the tubes were cooled to room temperature under tap water. 5 ml iso-amyl alcohol was added to it, the contents were mixed vigorously and to it, 0.1 ml ammonium thiocyanate solution was added. The tubes were shaken well and centrifuged at 3000 rpm for 10 min. Colour intensity in the alcohol was read exactly after 15 min of addition of ammonium thiocyanate at 465 nm against iso-amyl alcohol blank. For plotting a standard curve, 0.1 to 1.2 ml standard phytate solution containing 20-240 µg phytic acid was taken and made to 1.4 ml with water. The phytic acid was calculated by the formula:

$$\text{Phytic acid (mg/100 g)} = \frac{M \times V \times 100}{W \times V_1 \times 1000}$$

where, M = concentration of sample for graph

W = weight of sample

V = volume of extract made

V_1 = volume of aliquot taken

2.4.6 *In vitro* protein digestibility

The *in vitro* protein digestibility was carried out by using the modified method of Mertz *et al.* (1983). 200 mg of sample was weighed and transferred to a centrifuge tube. To it, 20 ml of pepsin reagent was added. The tube was stoppered and arranged in a shaker-incubator maintaining the temperature at 37°C for 3 h. Then, the centrifuge tube was removed and cooled. 5 ml of 50 per cent TCA was added and the contents were centrifuged at 10,000 rpm for 10 min at room temperature and filtered. 10 ml of aliquot was taken and dried in hot air oven. Dried aliquot was digested for nitrogen determination by using Microkjeldahl method (AOAC 2012). Digested protein of sample was determined. Protein digestibility was calculated by following formula given as under:

$$\text{Protein digestibility (\%)} = \frac{\text{Digested protein}}{\text{Total protein}} \times 100$$

2.5 Functional properties

2.5.1 Water absorption capacity

Water absorption capacity was determined as per method of Quinn and Paton (1979). Distilled water (3.5 ml) was added to a 100 mg sample in a pre weighed centrifuge tube. The mixture was vortexed for 2 min, left to rest for 30 min and then centrifuged (20ºC, 18,000 × g, 10 min). Supernatant was removed; the centrifuged tubes were turned upside down for 30 min and weighed (hydrated sample + tube weight).

Water absorption capacity

$$= \frac{\text{Weight of hydrated sample (g)} - \text{Weight of original sample (g)}}{\text{Sample weight (g)}}$$

2.5.2 Oil absorption capacity

Oil absorption capacity was determined by the method of Singh and Singh (1991). The sample (0.5 g) was mixed with oil (5 ml) in pre weighed centrifuge tubes. The tubes were vortexed for 2 min to get the complete dispersion of the sample in the oil. Samples were then allowed to stand for 30 min and then centrifuged at 3000 × g for 30 min. The separated oil was then removed with a pipette and the tubes were inverted for 30 min to drain the oil prior to reweighing. The oil absorption capacity was expressed as grams of oil absorbed per gram of the sample.

2.5.3 Bulk density

Bulk density was analyzed by using the method of Wang and Kinsella (1976). A known amount of sample was placed in a 25 ml graduated cylinder and packed by gently tapping the cylinder on the bench top 10 times from a height of about 5 cm. The volume of the sample was recorded. The bulk density was computed as g/ml of the sample.

$$\text{Bulk density (g/ml)} = \frac{\text{Weight of the sample}}{\text{Volume of the sample in cylinder}}$$

2.5.4 Swelling capacity

Swelling capacity was determined by the method of Robertson *et al.* (2000). The sample (500 mg) was weighed in a 10 ml measuring cylinder (0.1 ml graduation) and 10 ml of distilled water with 0.02% sodium azide was added. Then, the mixture was stirred gently to

eliminate trapped air bubbles and left on a level surface at room temperature to allow the sample to settle overnight. The volume (ml) occupied by the sample was measured and expressed as ml per gram of dry weight.

2.6 Statistical analysis

All the experiments were conducted in triplicates and the data were subjected to 't' test using SPSS 7.5 software to determine significant difference and values were expressed as Mean ± Standard error.

3. Results and Discussion

3.1 Antioxidant activity of soybean and *okara*

The phenolic content of plant material is correlated with their antioxidant activity (Garc, 2004). Phenolics are usually found in conjugated forms through hydroxyl groups with sugar and glycosides present in plant materials. The present study revealed that soybean had almost doubled the amount of total phenolic content (250.80 mg gallic acid/100 g) than that of *okara* (122.57 mg gallic acid/100 g) (Figure 1). The DPPH free radical scavenging activity of soybean (61.47 %) and *okara* (41.46 %) also differed significantly (p<0.01) (Figure 1). Soybean and its by-product *okara*, containing phenolic compounds, have been shown to possess antioxidant ability. Therefore, consumption of these natural antioxidants can be more effective and also economical than supplementation of synthetic antioxidants and these can protect against the risk of the occurrence of cardiovascular diseases, osteoporosis and cancers including those of breast, colon and prostate. Similar results for total phenolic content have been reported by Mujiae *et al.* (2011) for soybean and Singh *et al.* (2011) for *okara*. The results of present study for DPPH free radical scavenging activity of soybean are in agreement with those reported by Kumar *et al.* (2010). However, Singh *et al.* (2011) reported higher DPPH free radical scavenging activity of *okara* than that observed in the present study. Prabhakaran and Perera (2006) reported that the soybean processing method influenced the antioxidant content in *okara*.

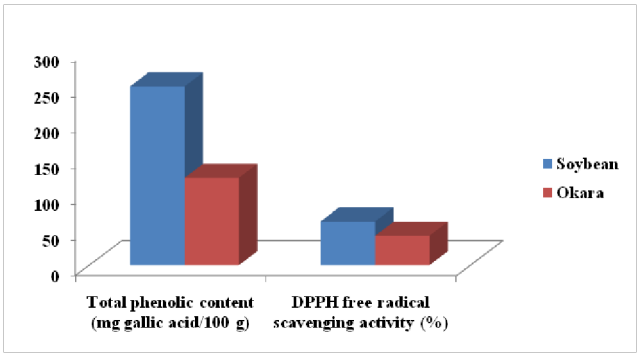

Figure 1: Antioxidant activity of soybean and *okara* (dry weight basis)

3.2 Nutrient composition of soybean and *okara*

3.2.1 Proximate composition

The data regarding proximate composition of soybean and *okara* are presented in Figure 2. The moisture content of soybean and *okara* were found to be 6.27 and 3.56 g/100 g, respectively, which differed significantly (p<0.01). Soybean had 36.16 g crude protein, 21.25 g crude fat and 5.46 g ash per 100 g which were significantly (p<0.01) higher than those in *okara*, *i.e.*, 24.79, 10.52 and 3.58 g/100 g, respectively. On the other hand, *okara* had significantly (p<0.01) more amounts of crude fibre (19.83 g/100 g) and total carbohydrate (37.71 g/100 g) when compared to those in soybean, *i.e.*, 7.50 and 23.37 g/100 g, respectively. *Okara*, by-product of soybean had appreciable amounts of protein, fat and fibre making it nutritionally rich. Wang and Cavins (1989) reported that *okara* had good protein quality and a superior protein efficiency ratio, which shows a potential source of low cost vegetable protein for human consumption. The results of present study are within the range of those reported earlier by Varsha Rani *et al.* (2008) for protein, fat and ash and Mujiae *et al.* (2011) for fat and protein of soybean. The findings of present investigation are comparable to those reported previously by Jimenez-Escrig *et al.* (2008) for protein, fat and fibre contents of *okara*.

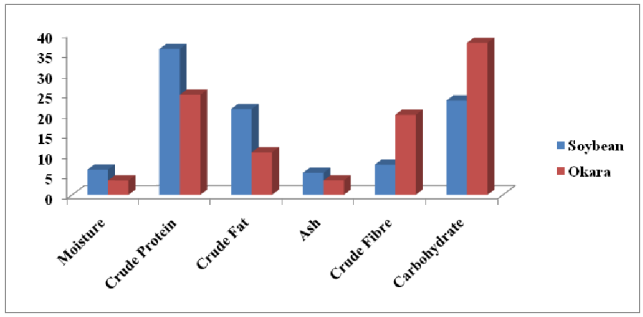

Figure 2: Proximate composition of soybean and *okara* (g/100g, dry weight basis).

3.2.2 Dietary fibre contents

Fibre is gaining more attention these days as it has preventive role in many diseases. The total, soluble and insoluble dietary fibre contents of *okara* were 58.21, 11.57 and 46.64 g/100 g, respectively, which were significantly (p<0.01) higher than that of soybean, *i.e.*, 24.75, 4.37 and 20.38 g/100 g, respectively (Table 1). Li *et al.* (2013) reported that dietary fiber in *okara* can protect against coronary heart disease, reduce blood pressure, blood cholesterol and prevent the occurrence of constipation and colon cancer. It also regulates diabetics' blood sugar levels. Due to these effects, dietary fiber is called the seventh nutrient by nutritionists. Furthermore, soluble dietary fiber plays an important role in the reduction of cholesterol levels in some hyperlipidemic individuals (Reynolds *et al.*, 2006) and it can also improve glucose tolerance in diabetics (Jenkins *et al.*, 2002). On the other hand, insoluble dietary fiber plays an important role in preventing constipation and irritable bowel movements by increasing faecal bulk and reducing gastrointestinal transit time (Bosaeus, 2004). Similar results were reported by Espinosa-Martos and Ruperez (2009) and Mateos-Aparicio *et al.* (2010a) for total and insoluble dietary fibre of *okara* and Lu *et al.* (2013) for total dietary fibre of *okara*, whereas, Espinosa-Martos and Ruperez (2009), Mateos-Aparicio *et al.* (2010a) and Lu *et al.* (2013) reported slightly lower values for soluble dietary fibre of *okara* than that of present study. This could be due to difference in variety of soybean or the processing method used.

3.2.3 Total mineral contents

Among the total mineral contents studied, the total calcium and phosphorus contents of *okara* were 346.93 and 480.17 mg/100 g,

respectively (Table 2) which were significantly (p<0.01) higher than those found in soybean, *i.e.*, 250.20 and 308.41 mg of calcium and phosphorus per 100 g, respectively. Potassium content of soybean (1489.67 mg/100 g) was significantly (p<0.01) higher than that of *okara* (1370.33 mg/100 g). A significant (p<0.01) difference was observed in iron and zinc contents of soybean and *okara* with total iron and zinc contents in *okara* as 6.82 and 7.04 mg/100 g, respectively, while in soybean the respective values were 8.28 and 7.86 mg/100 g. The values in present study are within the range of those reported earlier by Varsha Rani *et al.* (2008) for Ca, Fe and Zn of soybean. Similar results were reported by Stanojevic *et al.* (2014) for Ca, P, Fe and Zn of *okara*. However, Lu *et al.* (2013) reported higher values for Ca and Fe and lower values for K and Zn in *okara*.

Table 1: Dietary fibre contents of soybean and *okara* (g/100 g, dry weight basis)

Parameter	Soybean	*Okara*	't' value
Total dietary fibre	24.75 ± 0.17	58.21 ± 0.26	107.53**
Soluble dietary fibre	4.37 ± 0.04	11.57 ± 0.09	73.41**
Insoluble dietary fibre	20.38 ± 0.10	46.64 ± 0.24	101.36**

Values are mean ± SE of three independent determinations
** Significant at 1% level

Table 2: Total mineral contents of soybean and *okara* (mg/100 g, dry weight basis)

Parameter	Soybean	*Okara*	't' value
Calcium	250.20 ± 1.47	346.93 ± 3.19	27.55**
Phosphorus	308.41 ± 4.91	480.17 ± 7.78	18.67**
Potassium	1489.67 ± 12.25	1370.33 ± 11.67	7.05**
Iron	8.28 ± 0.01	6.82 ± 0.09	16.24**
Zinc	7.86 ± 0.03	7.04 ± 0.02	0.73**

Values are mean ± SE of three independent determinations
** Significant at 1% level

3.2.4 Available minerals

The data presented in Figure 3 indicated that the availability of calcium (40.28%), iron (22.36%) and zinc (30.25%) were significantly (p<0.01) higher in *okara* than those of soybean (35.87%, 18.53% and 25.75%). Jiménez-Escrig *et al.* (2008) evaluated the calcium, magnesium and zinc metabolism in rats fed on a diet supplemented with *okara* and observed a significant increase in calcium absorption due to the increased calcium solubility in the colon. The composition of *okara* depends on the procedure followed (Chinese or Japanese) to obtain it. In this study, the *okara* was obtained by the Chinese method, so the rehydrated soybean seeds were ground and filtered.

3.2.5 Antinutritional factor and *in vitro* digestibility

The limiting nutritional quality of soybean is mainly due to the presence of antinutritional factors. The phytic acid content of *okara* (843.33 mg phytic acid per 100 g) was significantly less than that of soybean (1386.67 mg phytic acid per 100 g), whereas, *in vitro* protein digestibility of *okara* was found to be 68.26 per cent which was significantly (p<0.01) more than that of soybean, *i.e.*, 56.46 per cent (Table 3). The values of phytic acid and *in vitro* protein digestibility in present study are within the range of those reported earlier by Varsha Rani and Grewal (2009) for soybean. However, Espinosa-Martos and Ruperez (2009) reported higher *in vitro* protein digestibility of *okara* than that observed in the present study.

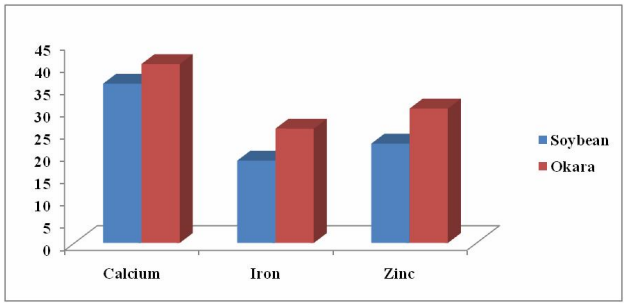

Figure 3: Mineral availability of soybean and *okara* (%, dry weight basis).

Table 3: Phytic acid and *in vitro* protein digestibility of soybean and *okara* (dry weight basis)

Parameter	Soybean	*Okara*	't' value
Phytic acid (mg/100 g)	1386.67 ± 13.33	843.33 ± 8.82	33.99**
In vitro protein digestibility (%)	56.46 ± 0.54	68.26 ± 0.44	16.77**

Values are mean ± SE of three independent determinations
** Significant at 1% level

Table 4: Functional characteristics of soybean and okara flour

	Water absorption capacity (ml/g)	Oil absorption capacity (ml/g)	Swelling capacity (ml/g)	Bulk density (g/ml)
Soybean	1.86 ± 0.02	0.86 ± 0.02	3.47 ± 0.05	0.61 ± 0.02
Okara	9.47 ± 0.10	0.26 ± 0.04	9.33 ± 0.07	0.21 ± 0.01
't' value	69.50**	14.89**	69.03**	23.53**

Values are mean ± SE of three independent determinations
** Significant at 1% level

3.3 Functional characteristics of soybean and *okara* flour

The functional properties of soybean and *okara* flour as presented in Table 4 revealed that the water absorption (9.47 ml/g) and swelling (9.33 ml/g) capacity of *okara* were significantly (p<0.01) higher as compared to those of soybean (1.86 ml/g and 3.47 ml/g). *Okara* had significantly (p<0.01) lower oil absorption capacity (0.26 ml/g) and bulk density (0.21 g/ml) as compared to soybean (0.86 ml/g and 0.61 g/ml). Similar findings were also reported by Espinosa-Martos and Ruperez (2009) and Mateos-Aparicio *et al.* (2010) for water retention, oil retention and swelling capacity of *okara*. On the other hand, Wachiraphansakul and Devahanstin (2007) and Ali *et al.* (2012) reported higher values for bulk density of *okara* and bulk density, water and oil absorption capacity of soybean flour as compared to that observed in the present study. The functional properties are important from commercial production point of view as they help to know the nature of developed product. Lower the bulk density and oil absorption capacity of raw ingredient, more the nutrients are dense and less oil absorptive food product can be developed. Foods with high water absorption capacity have low caloric value, thus helps in weight reduction.

4. Conclusion

It may be concluded from the present study that *okara* contained high quantity of vegetable protein, dietary fibre with remarkable amount of fat and minerals and antioxidants and also possessed good functional properties. The presence of antioxidants may have beneficial health effects which ultimately results in improvement in the health status of community. Thus, soy byproduct *okara* should be exploited for industrial use in developing value added products whose consumption will be a suitable solution for malnutrition problems for poor people.

Conflict of interest

We declare that we have no conflict of interest.

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