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Full Length Research Paper

Nutrient composition and functional properties of bean flours of three soya bean varieties from Ghana

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The proximate nutrients composition, mineral (calcium, magnesium, iron and phosphorus) concentrations and functional properties of bean flours of three soya bean varieties were investigated using standard analytical methods to assess their potential use as functional ingredients in the food industry. Moisture, ash, crude protein, crude fat, crude fibre, carbohydrate and energy were in the range of 1.02% - 1.80%, 1.01% - 1.67%, 36.94% - 40.01%, 16.82% - 19.30%, 2.97% - 3.01%, 34.97% - 39.86% and 458.58 kCal/100 g - 473.62 kCal/100g respectively. Calcium, magnesium, iron and phosphorus were in the range of 62.93 mg/100g - 217.38 mg/100g, 8.39 mg/100g - 8.53 mg/100g, 3.86 mg/100g - 11.51 mg/100g and 0.88 mg/100g - 2.33 mg/100g respectively. Water absorption capacity differed between 254.76% and 322.15%. Swelling power ranged between 4.25 and 4.66. The values for solubility ranged between 14.31% and 20.12%. Bulk density values ranged between 1.56 g/cm^3 and 2.09 g/cm^3. Considering the nutrient contents and the functional properties of the studied flour samples, the flour samples should be an inexpensive source of macronutrients that could be used in the management of protein-energy malnutrition and to improve the nutrition status of the vulnerable group of the population in developing countries. In developed countries, they could be used to improve the nutrition status of functional foods.

Keywords: Proximate nutrients, functional properties, macronutrients.

INTRODUCTION

Plant protein products are gaining increased interest as ingredients in food systems throughout many parts of the world; the success of utilizing plant proteins as additives depends greatly upon the favourable characteristics that they impart to food (Adebowale *et al*., 2005). According to Marcello and Gius (1997), plants proteins are now regarded as versatile functional ingredients or as biologically active components more than as essential nutrients in the developed countries. Sirtori and Lovati (2001) contend that plant food diets increase the level of fibre intake which reduces the risk of bowel diseases. The partial replacement of animal foods with legumes is claimed to improve overall nutritional status (Guillion and Champ, 1996).

A large variety of oilseeds and pulses, including cowpeas, groundnuts, pigeon peas and melon seeds grow well in Ghana. These form parts of the traditional diets of many people in Ghana. Cowpea for instance is used in foods such as koose (cowpea fritters), garri and beans (roasted grated fermented cassava and cooked beans) and tugbani (steamed bean cake). It is also used in stews and soups (Appiah *et al*., 2011). Soya beans (*Glycine max*) have recently become popular in the West African sub-region due to their high protein content. It is an annual leguminous crop and is grown to provide food for humans, feed for animals and raw materials for industry (Abbey *et al*., 2001). Soya bean is an excellent source of protein (35-40%). The soya bean seed is the richest in food value of all plant foods consumed in the world (Kure *et al*., 1998). It is used in the production of bread as composite flour (Kure *et al*., 1998; Dhingra and Jood, 2002; Basman *et al*., 2003). In Ghana, traditional food uses of soya beans are very limited. There is the need for the people to be educated on the nutritional benefits of soya beans in order to promote their use in the diets of people. For soya beans to be used effectively to improve the nutrition status of people, there is the need for thorough research into the process characteristics, nutritional quality and consumer acceptability of soya beans and blends into which soya bean flour has been incorporated.

The object of this study was to investigate the functional properties and the nutrient content of these soya bean varieties to determine the potential of the flours from these soya bean varieties in food formulations. The results from this study can potentially expand the usage of the flours from these soya bean varieties.

MATERIALS AND METHODS

Source of raw materials

The soya bean varieties used in this study were obtained from the Savannah Agricultural Research Institute, Tamale in the Northern region of Ghana. Three (3) varieties of soya beans namely Salintuya-1, Quarshie and Jenguma were used for the study.

Soya bean flour preparation

The soya bean seeds were soaked in water for 24 hours. The soaked beans were placed in a sieve and the water drained off. The beans were then boiled (blanched) for 20 minutes to inactivate enzyme activity and also to make decortication (testa removal) easy. The water was then drained. The dehulled beans were then solar dried after which they were roasted at 120°C for 30 minutes. The roasted beans were milled with a laboratory miller (Cyclotec 1093 Sample Mill, Tecator, Sweden) into flour. The flour was sieved through a net with a 75µm mesh size.

Sample analysis

Proximate nutrients determination

Moisture, ash, crude protein, crude fat and crude fibre were determined by the method of the Association of Official Analytical Chemists' (AOAC, 1990). Total percentage carbohydrate was determined by the difference method as reported by Onyeike *et al*. (1995). This method involves adding the total values of crude protein, crude fat, crude fibre, moisture and ash constituents of the sample and subtracting it from 100. The value obtained is the percentage carbohydrate constituent of the sample.

Energy determination

Energy content was obtained by multiplying the mean values of crude protein, crude fat and total carbohydrate by the Atwater factors of 4, 9, 4 respectively, taking the sum of the products and expressing the result in kilocalories per 100 g sample as reported by Edem *et al*. (1990) and Onyeike *et al*. (1995)

Minerals determination

Calcium, iron and magnesium were determined by Atomic Absorption Spectrophotometry (Agte *et al*., 1995) and the phosphorus determination was done based on the method described by Jackson *et al*. (1974).

Functional properties determination

Bulk density

Bulk density was determined by using the procedure of Okaka and Potter (1979). Fifty grams (50g) of soya bean flour was transferred into a 100 ml measuring cylinder and tapped to a constant volume. The bulk density (g/cm^3) was calculated using the formula:

$$\text{Bulk density} = \text{weight of flour (g)}/\text{flour volume } (cm^3)$$

Solubility and swelling power

Solubility and swelling power were determined based on a modification of the method of Leach *et al*. (1959). One gram of the flour sample was transferred into a pre-weighed graduated centrifuge tube (50 ml). Distilled water was added to give a total volume of 40 ml. The suspension was stirred just sufficiently and uniformly avoiding excessive speed. The sample in the centrifuge tube was heated at 85˚C in a thermostatically regulated temperature water bath for 30 minutes with constant stirring. The tube was removed, wiped dry on the outside and cooled to room temperature. It was then centrifuged for 15 minutes at 2200 rpm. The solubility was determined by evaporating the supernatant and weighing the residue. The sediment was also weighed. The percentage (%) solubility and swelling power were then calculated. Percentage solubility and swelling power were calculated as follows:

$$\% \text{ Solubility} = \frac{\text{weight of residue} \times 100}{\text{Weight of sample}}$$

Table 1. Proximate (%) and energy (kCal/100g) composition of flours of soya bean

Variety	Moisture	Ash	Crude protein	Crude fat	Crude fibre	*Carbohydrate	**Energy
Salintuya-1	1.08^{b}(±0.25)	1.67^{a}(±0.05)	40.01^{a}(±0.41)	19.30^{a}(±0.34)	2.97^{a}(±0.32)	34.97	473.62
Quarshie	1.02^{c}(±0.01)	1.01^{c}(±0.00)	39.25^{a}(±0.33)	17.05^{b}(±0.14)	2.98^{a}(±0.35)	38.69	465.21
Jenguma	1.80^{a}(±0.04)	1.57^{b}(±0.18)	36.94^{b}(±0.22)	16.82^{b}(±0.20)	3.01^{a}(±0.43)	39.86	458.58

The values for moisture, ash, crude protein, crude fat and crude fibre are means ± standard deviations of triplicate determinations. Values in the same column with the same superscript letters are not significantly different ($p > 0.05$).
*Values were obtained by adding the mean figures of moisture, ash, crude protein, crude fat and crude fibre and subtracting from 100.
**Values were obtained by multiplying the mean figures of crude protein, crude fat and carbohydrate by the Atwater factors of 4, 9 and 4 respectively and summing the products up.

$$\text{Swelling power} = \frac{\text{weight of sediment} \times 100}{\text{Weight of sample (dry basis)} \times (100 - \%\ \text{solubility})}$$

Water absorption capacity (WAC)

Water absorption capacity (WAC) was determined at 25˚C according to the method of Yamazaki (1953) as modified by Medcalf and Gilles (1965). An aqueous suspension was made by dissolving 2 g of the flour sample in 40 ml of water. The suspension was agitated for 1 hour on Griffin flask shaker after which it was centrifuged for 10 minutes at 2200 rpm. The free water was decanted from the wet sample and drained for 10 minutes by inverting the tubes over filter paper placed in a flask and wet sample weighed. Percent WAC was calculated as follows:

$$\%\ \text{WAC} = \frac{\text{weight of water bound} \times 100\ \%}{\text{Weight of sample (dry basis)}}$$

Statistical analysis

The experiments in this study are reported as mean ± standard deviation of triplicate determinations. The statistical analysis of data was by Analysis of Variance (ANOVA) at 5 % level of significance using the programme ASSISTAT Version 7.5 beta (2011). Means were separated using the Duncan's multiple range statistical test.

RESULTS

Proximate nutrients and energy composition of soya bean varieties

The proximate nutrients and energy composition of the soya bean varieties are presented in Table 1. The moisture content ranged from 1.02% in Quarshie to 1.80% in Jenguma. These figures differ far from the 6.11% moisture of soya bean flour given by Edema *et al*. (2005). The difference in values may be due to the processing methods. The flours in this study were obtained after roasting the soya beans. The application of heat during the roasting might have driven most of the moisture away. The three soya bean varieties differed significantly ($p < 0.05$) in moisture content.

The ash content ranged from 1.01% to 1.67% with Salintuya-1 having the highest ash content while Quarshie had the lowest. The ash content of the soya bean varieties differed significantly ($p < 0.05$) from each other. Crude protein content ranged from 36.94% in Jenguma to 40.01 % in Salintuya-1. The values obtained for the crude protein for the soya bean varieties differed significantly ($p < 0.05$) from each other. The crude protein values obtained compare favourably with the value of 36% given by Edema *et al*. (2005). The crude fat content ranged from 16.82% to 19.30% with Jenguma having the least and Salintuya-1 the highest. The crude fat contents of the soya bean varieties differed significantly ($P < 0.05$) from each other. The crude fibre content of Salintuya-1, Quarshie and Jenguma were 2.97%, 2.98% and 3.01% respectively. No significant difference ($p > 0.05$) in crude fibre values was observed for Salintuya-1, Quarshie and Jenguma. The carbohydrate content of the flours ranged from 34.97% in Salintuya-1 to 39.86% in Jenguma. These figures compare favourably with the value of 40.67% given by Edema *et al*. (2005).

The energy content was highest in Salintuya-1 (473.62 kCal/100g), followed by Quarshie (465.21 kCal/100g) and lowest in Jenguma (458.58 kCal/100g)

Mineral concentrations of flour samples of soya bean varieties

The mineral (calcium, magnesium, iron and phosphorus) concentrations (mg/100g) of the flour samples of the soya

Table 2. Mineral concentrations (mg/100g) of the flours of the soya bean varieties

Variety	Calcium	Magnesium	Iron	Phosphorus
Salintuya-1	217.38^{a}(±2.11)	8.53^{a}(±0.04)	11.51^{a}(±(0.15)	0.88^{c}(±0.00)
Quarshie	156.63^{c}(±0.87)	8.43^{c}(±0.43)	11.04^{c}(±0.98)	1.09^{b}(±0.01)
Jenguma	62.93^{b}(±1.04)	8.39^{b}(±0.42)	3.86^{b}(±0.02)	2.33^{a}(±0.31)

Values are means ± standard deviations of triplicate determinations. Values in the same column with the same superscript letters are not significantly different (p > 0.05).

Table 3. Functional properties of flours of soya bean varieties

Variety	*WAC(%)	Swelling power	Solubility (%)	Bulk density(g/cm^3)
Salintuya-1	257.74^{b}(±7.09)	4.34^{a}(±0.16)	17.99^{b}(±0.14)	1.80^{b}(±0.00)
Quarshie	254.76^{b}(±6.40)	4.25^{a}(±0.11)	14.31^{c}(±0.15)	2.09^{a}(±0.00)
Jenguma	322.15^{a}(±10.60)	4.66^{a}(±0.33)	20.12^{a}(±0.70)	1.56^{c}(±0.00)

Values are means ± standard deviations of triplicate determinations. Values in the same column with the same superscript letters are not significantly different (p > 0.05).
*WAC-Water absorption capacity

bean varieties are presented in Table 2. Calcium content ranged from 62.93 mg/100g in Jenguma to 217.38 mg/100g in Salintuya-1. Statistical analysis revealed a significant difference ($p < 0.05$) in calcium contents among the three soya bean varieties. The magnesium content differed between 8.39 mg/100g for Jenguma and 8.53 mg/100g for Salintuya-1. The magnesium content of the three soya bean varieties differed significantly ($p < 0.05$) from each other. There were significant differences ($p < 0.05$) among the iron content of the three soya bean varieties. The values ranged from 3.86 mg/100g in Jenguma to 11.51 mg/100g in Salintuya-1. The phosphorus content of the three soya bean varieties differed between 0.88 mg/100g for Salintuya-1 and 2.33 mg/100g for Jenguma.

Functional properties of the soya bean flours

The functional properties of the soya bean flours are shown in Table 3. Water absorption capacities of the flours ranged from 254.76% in Quarshie to 322.15% in Jenguma. These figures differed significantly from each other. Swelling power ranged between 4.25 for Quarshie to 4.66 for Jenguma. Statistical analysis revealed no significant difference ($p > 0.05$) in the swelling power values for the three soya bean varieties. The swelling power results obtained are consistent with the observation of Hossou and Ayernor (2002) who reported that the swelling power increased with increasing water absorption capacity. The values obtained are close to the value of 5.89 reported for soya bean flour by Edema *et al.* (2005).

Solubility (%) ranged from 14.31 % in Quarshie to 20.12% in Jenguma. The solubility values for the three soya bean varieties differed significantly ($p < 0.05$) from each other. Bulk densities of 1.80 g/cm^3, 2.09 g/cm^3 and 1.56 g/cm^3 were obtained for Salintuya-1, Quarshie and Jenguma respectively. The flour samples of the three soya bean varieties differed significantly ($p < 0.05$) in bulk densities from each other.

DISCUSSION

Proximate nutrients and energy composition of soya bean flours

The flour samples of the soya bean varieties recorded very low moisture contents in the range of 1.02% to 1.80%. The very low moisture content of these flour samples imply they will store for a very long time since moisture which is an important medium for multiplication of microorganisms is very low in these flour samples.

The ash contents of the flour samples ranged from 1.01% in Quarshie to 1.67 % in Salintuya-1. The ash contents are indicative that the flour samples could be important sources of minerals. The flour samples of the soya bean varieties recorded high crude protein figures in the range of 36.94% to 40.01%. Salintuya-1 recorded the highest crude protein content and therefore could be a superior source of protein to the other studied varieties. The high protein content of the studied varieties suggests that they could be used in the management of protein-deficiency cases such as Kwashiorkor. The crude fat levels of the studied flour samples were high ranging from 16.82% to 19.30%. This means these flour samples could be used in improving the palatability of foods in which they are incorporated. These results also suggest that soya beans may be viable sources of oil going by their crude fat contents. With regard to crude fibre contents, it ranged from 2.97% in Salintuya-1 to 3.01% in Jenguma. This suggests that the minerals in Salintuya-1 would be better available for absorption than the minerals in the other flour samples since foods with high fibre contain equally high amounts of phytate (Harland and Oberleas, 1985) and dietary levels of phytate of 1% or more have been reported to interfere with mineral availability (Erdman, 1979). The flour samples also recorded high carbohydrate contents ranging from 34.97% in Salintuya-1 to 39.86% in Jenguma. The high carbohydrate contents of these flour samples suggests that these flour samples could be used in managing protein-energy malnutrition since there is enough quantity of carbohydrate to derive energy from in order to spare protein so that protein can be used for its primary function of building the body and repairing worn out tissues rather than as a source of energy.

The energy values (kCal/100g) of 458.58, 465.21 and 473.62 for Jenguma, Quarshie and Salintuya-1 indicate that 599.68g, 591.13g and 580.63g of these flour samples would, respectively provide 2750kCal – an energy value which falls within the range of the daily calorie requirement of 2500 to 3000 killocalories for adults (Onyeike and Oguike, 2003).

Mineral concentration of soya bean flours

Calcium contents ranged from 62.93 mg/100g in Jenguma to 217.38 mg/100g in Salintuya-1. These figures suggest that these flour samples could be used in complementary foods to help build the bones and teeth of infants since calcium is one of the main components of teeth and bones. Calcium also plays a role in blood clotting (Mehas and Rodgers, 1997). The magnesium content of the flour samples range from 8.39 mg/100g in Jenguma to 8.53 mg/100g in Salintuya-1. The figures suggest that Salintuya-1 is a superior source of magnesium than the other varieties. Magnesium is involved in making proteins and releasing energy, and helps hold calcium in the enamel of the teeth (Mehas and Rodgers, 1997). The contents of iron in the studied flour samples ranged from 3.86 mg/100g in Jenguma to 11.51 mg/100g in Salintuya-1. The iron contents obtained for these flour samples suggest that Salintuya-1 is a superior source of iron and could be better used in the management of iron-deficiency anaemia than the other flour samples since iron is a vital part of red blood cells that carry and release oxygen (Mehas and Rodgers, 1997). The contents of phosphorus ranges from 0.88 mg/100g in Salintuya-1 to 2.33 mg/100g in Jenguma. These figures suggest that Jenguma could supply more phosphorus than the other flour samples. Phosphorus is closely linked with calcium. The two minerals combine to form calcium phosphate, which give bones their rigid structure (Mehas and Rodgers, 1997).

Functional properties of soya bean flour

Functionality as applied to food ingredients is defined as any property, aside from nutritional attributes, that influences the ingredient's usefulness in food (Arijawansa, 2000). The use of any flour as food ingredient is dependent on the water-flour interaction, which determines the rehydration of flour (Ndie *et al*., 2010). The major chemical compositions that enhance the water absorption capacities of flours are proteins and carbohydrates, since these constituents contain hydrophilic parts, such as polar or charged side chains (Lawal and Adebowale, 2004). Values for the water absorption capacities of the flour samples ranged from 254.76% in Quarshie to 322.15% in Jenguma. According to Aletor *et al*. (2002), water absorption capacities ranging from 149.1% to 471.5% are considered critical in viscous foods such as soups and gravies. Hence these soya bean flours may find use as functional ingredients in soups, gravies and baked products. They could also be used as thickeners in liquid and semi-liquid foods since they have the ability to absorb water and swell for improved consistency in food (Fasasi *et al*., 2007).

Swelling power results ranged from 4.25 in Quarshie to 4.66 in Jenguma. The relatively high swelling power for Jenguma means that it will be the best among the studied flour samples to be incorporated into products to improve the consistency since a relatively smaller amount will be needed to swell to achieve the desired consistency. The flours generally gave high swelling power values, suggesting that they could be useful in food systems where swelling is required. The values for solubility range from 14.31% in Quarshie to 20.12% in Jenguma. These figures suggest that the nutrients in Jenguma could be better absorbed than the nutrients in the other flour samples because of its high solubility which could facilitate absorption of nutrients by the body.

The flour samples gave very high bulk densities ranging from1.56g/cm^3 in Jenguma to 2.09 g/cm^3 in Quarshie. These figures indicate that the flours are heavy. Looking at the figures Quarshie will be the heaviest followed by Salintuya-1, with Jenguma being the lightest. Since Jenguma is the lightest, it would occupy more space per unit weight and therefore would require more packaging material leading to high packaging cost. According to Akpata and Akubor (1999), low bulk density would be an advantage in the formulation of complementary foods. This implies among the studied flour samples Jenguma will be the most suitable for formulation of complementary foods because of its low bulk density.

CONCLUSION

The study has established the proximate nutrients, mineral (calcium, magnesium, iron and phosphorus) concentrations as well as some functional properties of the flour samples from the soya bean varieties. The results of this study indicate that the flour samples are rich in proteins, fats and carbohydrates and are therefore inexpensive source of macronutrients which can be used in intervention programmes aimed at alleviating protein-energy malnutrition. The flours from these soya bean varieties also have good functional properties. The good functional properties of these flours suggest that they could be useful in gravies, sauces, soups, stews and bakery products. The flours have good protein contents and could be used to fortify flours with low protein content such as maize and rice. The mineral contents indicate that the flour samples could be important sources of minerals for humans and farm animals.

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