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Some Physical Properties of Ten Soyabean Varieties and Effects of Processing on Iron Levels and Availability

G. Oluyemisi Latunde-Dada

Department of Biochemistry, Obafemi Awolowo College of Health Sciences, Ogun State University, Ago-Iwoye, Nigeria

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ABSTRACT

Ten Nigerian soyabean varieties were investigated for physical properties, iron levels and dialyzable iron. The seed coat accounted for 6·01–9·50% of the weight of the seeds; leached solids, 6·95–15·34%; swelling capacity, 99·3–197·7%, and the seed density ranged from 1·82 to 2·36 g/cm^3*. There were no significant differences for most of the soyabean varieties in the iron levels of the whole, dehulled and cooked soyabean samples. While roasting conditions did not significantly (*$P > 0{\cdot}05$*) influence the dialyzable iron, dehulling led to significant decreases in the diffusibility of iron. The percentages of dialyzable iron from defatted flour, soya concentrate and soya isolate respectively, were 2·26, 2·12 and 2·49 after the 2 h pancreatic digestion. The dialyzable iron from the Nigerian home-made soya products ranged from 3·91 to 13·6%. Germination and fermentation enhanced the availability of iron. The implications of these observations in relation to iron nutrition are discussed.*

INTRODUCTION

Legume proteins, particularly those obtained from soyabeans (*Glycine max* L) are playing an important role in meeting the dietary needs of peoples in affluent countries. In these countries, advances in technology have made possible the manufacture of a wide range of soya products which are used as supplementary and complementary protein extenders in foods. The functional properties of soyabean proteins have thus been fully utilized

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(Kinsella, 1979). These technological advances are unavailable in the developing countries where soyabean could play a significant role in the dietary protein needs. In Nigeria, for example, imported soya products are prohibitively expensive. The utilization of these 'God-sent Golden beans' (Singh, 1987) in Nigeria has therefore followed the native methods commonly encountered in South East Asian countries.

Within the last 10 years, the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria, has developed and released soyabean varieties which are best suited to the climatic conditions in Nigeria. The acceptability of soyabeans by Nigerians was initially very poor because of the longer cooking time when compared with the more commonly acceptable cowpeas (*Vigna unguiculata*) and because of the beany flavour associated with the beans (Nelson *et al.*, 1979). Attempts have also been made at developing home- and village-level preparation of soya foods. Examples of such products include soya milk, soya–cereal mixes, boiled soyabeans, soya condiments and snacks. Some of the difficulties in soya preparation are being overcome by employing the simple processing procedures of cracking, soaking and dehulling. It is imperative, therefore, to assess the contributions of Nigerian soyabean varieties and that of the home-made soya products to the iron nutrition of the Nigerian populace, more especially since this protein source is being advocated as a good substitute for meat (a highly bio-available iron source).

Earlier studies have indicated the inhibitory effects of commercially processed soya proteins on meat iron availability (Cook *et al.*, 1981; Hallberg & Rossander, 1982; Latunde-Dada & Neale, 1986). Attempts were made in the current studies to evaluate some physical properties of ten locally grown soyabean varieties and the effects of processing on the iron levels of these soyabeans. Furthermore, an in-vitro iron availability technique was employed to study the percentage dialyzable iron from a number of home-made soyabean products.

MATERIALS AND METHODS

The soyabean seeds and some soya products were obtained from the IITA at Ibadan, Nigeria, defatted soyabean flour from British Arkady, Manchester, UK, soyabean concentrate from FPD/Hypac, Swindon, Wiltshire, UK, and soyabean isolate from Ralston Purina Company Limited, McAutey-Edwards Limited, Baldock, Herts., UK.

The home-made soya products were prepared according to the recipes developed by the Federal Department of Rural Development, Home Economics Division, Ibadan, Nigeria.

The physical properties were developed by a modification of Akinyele *et al.*'s (1986) methods.

Percent seed coat

Fifty seeds were weighed and soaked in 100 ml deionized water for 10 min. The seed coat was removed by hand, drained on filter papers (Whatman No. 1), weighed wet and reweighed after drying to constant weight in the oven. The final weight was expressed as percentage of total seed weight.

Swelling capacity

Fifty seeds of the soyabean varieties were weighed and cooked in boiling water for 50 min. The seeds were drained and reweighed. The final weights plus the leached solids were taken as the cooked weights. The swelling capacity was the difference between the raw weight and the cooked weight per 100 g seed. These seeds were used as the cooked samples.

Leached solids

Fifty seeds of each variety were cooked in 150 ml boiling water for 50 min. The seeds were removed and the bean broth was evaporated to dryness in a hot air oven at 80°C overnight. The weight of the residue was expressed in g% of the initial weight of the seeds before cooking.

Seed density

One hundred seeds were weighed and transferred into a measuring cylinder containing 100 ml of deionized water. The seeds were soaked for 10 min, for equilibration and the volume of water displaced was recorded. The mass and the volume were used in calculating the density. The seeds were soaked for an additional 2 h to obtain the soaked samples.

Reagents

Pepsin solution–pepsin powder (16 g from porcine stomach mucosa; Sigma Chemical Company, Poole, Dorset, UK) was prepared in 100 ml 0·1 M HCl. Pancreatin–bile extract/mixture: pancreatin (4 g; from porcine pancreas; Sigma Chemical Company) were suspended in 0·1 M sodium bicarbonate and the volume made to 1 litre with 0·1 M $NaHCO_3$. Protein precipitant solution: One hundred grams trichloroacetic acid, 100 g hydroxylamine hydrochloride and 100 ml concentrated HCl were dissolved in deionized water and made to a volume of 1 litre. Chromogen solution: Two hundred and fifty milligrams bathophenanthroline sulfonate was dissolved in 2M sodium acetate and brought to 1 litre with 2M sodium acetate.

Dialysis tubing: Molecular weight cut-off of approximately 12 000 (Sigma Chemical Company).

Analytical methods

Ten grams of soyabean sample was homogenized in 50 ml of deionized water. The pH of the homogenates was adjusted to 2 with 6M HCl, and the final weight adjusted to 100 g with 0·1M HCl. Pepsin solution (3 ml) was added to the homogenized sample and incubated in a shaking water bath for 2 h at 37°C. These 20 g aliquots of the pepsin digest were transferred into conical flasks. Segments of dialysis tubing containing 25 ml deionized water and an amount of $NaHCO_3$ equivalent to the titratable acidity (determined according to Miller *et al.*, 1981) were put in each flask. The flasks were incubated in the shaking water bath for about 30 min or until the pH was 5. Five millilitres of the pancreatin–bile extract mixture was then added and the incubation continued for another 2 h. After the pancreatic digestion, the dialysis tubes were removed and the contents were quantitatively transferred to a 25 ml volumetric flask and made to volume with deionized water.

$$\text{Dialyzable iron (\%)} = \frac{\mu\text{g Fe/ml dialysate} \times 25}{\mu\text{g Fe/ml sample} \times \text{weight of sample (g)}} \times 100$$

Iron determination—The soyabean samples were ashed and the iron estimation was carried out colorimetrically as described by Hurrell *et al.* (1988).

RESULTS AND DISCUSSION

The physical properties of the soyabean seeds (Table 1) showed that the seed coat weight ranged from 6·42–9·5%, seed density, 1·82–2·36 g/cm^3, swelling capacity was 99·3–197·7%, leached solids were 6·95–19·45%. Some physical properties of soyabeans have been shown to be important in the nutritional consideration of the legume (Kinsella, 1979). The swelling capacity (water absorption and binding) due to hydrogen-bonding and entrapment of water has been exploited in meat, sausages, breads and cakes. On the average, soyabeans have been reported to have 8% hull, 90% cotyledon and 2% hypocotyl (Levine *et al.*, 1982).

The iron levels of the whole, dehulled and cooked soyabeans are indicated

TABLE 1
Some Physical Properties of Ten Soyabean Varieties

Varieties	*Moisture (%)*	*Seed density (g/cm^{3})*	*Seed coat (%)*	*Swelling capacity (%)*	*Leached solids (g/%)*	*Seed weight (g/100 seeds)*
1 TGX 966-25^{E}	14·8	2·06^{c}	6·52^{f}	118·8^{d}	14·4^{bf}	15·3^{b}
2 TGX 849-313^{D}	14·4	2·6^{a}	9·26^{b}	127·7^{c}	17·7^{a}	12·2^{d}
3 TGX 1019-2^{E}	13·2	1·99^{c}	6·01^{g}	133·4^{b}	15·0^{f}	14·1^{cf}
4 TGX 536-2^{D}	10·3	1·82^{d}	7·28^{e}	116·7^{d}	6·95^{e}	12·63^{d}
5 TGX 1083-14^{E}	12·7	2·32^{b}	8·83^{c}	99·3^{e}	19·45^{a}	15·8^{b}
6 TGX 923-2^{E}	13·7	1·98^{ce}	4·46^{f}	197·7^{a}	15·34^{b}	9·5^{e}
7 Samsoy I	12·5	2·35^{b}	6·51^{f}	115·8^{d}	13·56^{bf}	12·6^{d}
8 TGX 984-2^{E}	13·6	1·84de	9·50^{a}	125·9^{c}	13·57^{cf}	14·8^{bf}
9 Bossier	17·14	2·08^{c}	6·42^{f}	114·6^{d}	10·83^{a}	19·63^{a}
10 TGX 996-28^{E}	12·5	2·27^{b}	8·06^{d}	127·4^{c}	18·5^{a}	11·6^{d}

Values in the same column followed by the same letter are not significantly different at $P > 0·05$ using the DMRT.

in Table 2. The iron levels of varieties TGX 1019-2^{E} and Samsoy I were significantly higher than for TGX 849-313. The iron level differences in all the other varieties were, however, not statistically ($P > 0·05$) significant. Cooking and dehulling led to significant ($P < 0·05$) losses of iron from the soyabean seeds. Commercially processed soyabeans are dehulled (Berger, 1981; Serrato, 1981) before extracting the oil and the concentration of the protein. Some local Nigerian recipes also involve the process of dehulling which, in the current study, shows a loss of from 14–35% iron. Cooking also

TABLE 2
Iron Levels of Whole, Dehulled and Cooked Soyabeans (mg/100 g)

Varieties	*Whole*		*Dehulled*		*Cooked*	
	Mean	*SEM*	*Mean*	*SEM*	*Mean*	*SEM*
1 TGX 996-25^{E}	4·32	0·23	3·24	0·25	2·98	0·30
2 TGX 849-313^{D}	3·48	0·21	2·28	0·20	2·90	0·02
3 TGX 1019-2^{E}	4·53	0·15	3·13	0·15	3·28	0·18
4 TGX 536-2^{D}	3·83	0·20	2·37	0·26	2·65	0·23
5 TGX 1083-14^{E}	4·27	0·50	3·14	0·16	3·43	0·21
6 TGX 923-2^{E}	4·20	0·38	2·91	0·29	3·58	0·34
7 Samsoy I	4·50	0·19	3·85	0·14	3·15	0·16
8 TGX 984-2^{E}	3·62	0·20	2·56	0·15	2·79	0·32
9 Bossier	3·71	0·19	2·51	0·18	2·99	0·09
10 TGX 996-28^{E}	3·91	0·21	2·88	0·08	3·08	0·05

TABLE 3
Dialyzable Iron (%) from Three Soya Products during *In-vitro* Digestion

Pancreatic digestion time	*Defatted flour*		*Soya concentrate*		*Soya isolate*	
	Mean	*SEM*	*Mean*	*SEM*	*Mean*	*SEM*
30 min	1·32	0·22	1·39	0·02	1·00	0·03
1 h	1·85	0·15	1·89	0·02	1·97	0·06
2 h	2·26	0·12	2·12	0·08	2·49	0·16
4 h	2·70	0·27	2·31	0·03	3·26	0·39

led to a loss of 15–31% iron in the broth. The incorporation of the hulls and broth in the preparation of the dishes is therefore recommended. Concentrating soya protein increased the level of iron in the products. Iron levels of the commercially processed soya products agreed with reported values (Steinke & Hopkins, 1978; Rotruck & Luhrsen, 1979).

The dialyzable iron values from the pancreatic digests of commercially processed soya products were generally low; the soya isolate had the highest dialyzable iron at the end of the 4 h pancreatic digestion (Table 3).

The poor iron availability from legumes has been attributed to their high polyphenolic content (Rao & Prabhavathi, 1982) and most importantly to

TABLE 4
Iron Content and Dialyzable Iron from Some Soya Products

Soya product	*Iron (mg/100 g)*		*Dialyzable iron (% of total)*	
	Mean	*SEM*	*Mean*	*SEM*
Defatted flour[a]	10·5	0·96	2·26	0·12
Soya concentrate	10·1	0·81	2·12	0·08
Soya isolate	9·3	0·25	2·51	0·19
Soya maize snack	5·85	0·29	5·06	0·23
Soya cassava biscuits	6·30	0·29	4·20	0·10
Soya wheat biscuits	6·21	0·05	3·91	0·15
Soya candies	5·13	0·29	5·62	0·10
Extruded full fat flour	6·03	0·12	6·95	0·19
Soya cereal (soyogi)	6·11	0·06	7·95	0·19
Extruded defatted flour	6·35	0·18	5·11	0·17
Defatted flour[b]	6·06	0·03	5·00	0·32
Fermented soyabeans	4·93	0·02	13·6	0·15
Germinated soyabeans	4·49	0·01	11·0	0·50

[a] Solvent extracted soya flour.
[b] Screw pressed soya flour.

the iron binding effects of phytate in the beans (Hallberg *et al.*, 1977). The dialyzable iron from the Nigerian home made soyabean products ranged from 3·91 to 13·6% (Table 4).

The concentration of soya protein up to the level found in the isolate did not significantly ($P > 0{\cdot}05$) affect the dialyzable iron. Schricker *et al.* (1982) also reported similarly low values of percent dialyzable iron from a wide range of soya products used for substituting egg white in a semisynthetic meal. Soya products processed for human consumption must undergo a form of heat treatment to inactivate the antinutritional factors (Wolf, 1970). Roasting of some of the soya varieties did not appreciably influence the dialyzable iron (Fig. 1). Baking was found to increase the bioavailability of

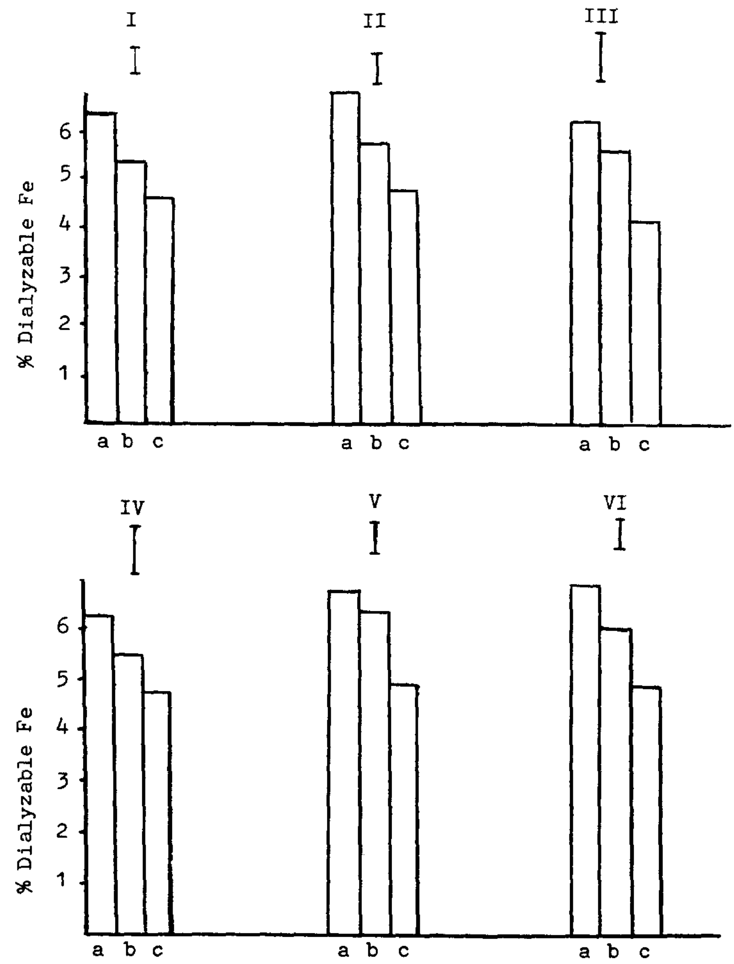

Fig. 1. Percentage dialyzable iron from: (a) whole raw; (b) roasted; (c) dehulled raw soyabeans. The varieties were: (I) TGX 996-25[E]; (II) TGX 849-313[D]; (III) TGX 1019-2[E]; (IV) SAMSOY I; (V) TGX 984-2[E]; (VI) Bossier. Vertical lines represent the LSDs.

iron to humans from whole soyabeans and isolated soya protein (Morck *et al.*, 1982). Steinke and Hopkins (1978) also reported an increase in iron availability when anaemic rats were fed autoclaved soya isolate. Fritz (1973), however, reported a decrease in iron availability when soyabeans were autoclaved and fed to rats.

Dehulled soyabean seeds had significantly ($P < 0{\cdot}05$) lower dialyzable iron than the whole seeds (Fig. 1). The bioavailability of iron from soya bean hulls has been found to be equivalent to that of ferrous sulphate (Weaver *et al.*, 1984; Johnson *et al.*, 1985). Most of the iron in soyabean hull was found to be in the highly available ferrous state (Laszlo, 1988). In the commercially processed soya products, the hulls may be incorporated into human foodstuffs without adversely affecting the quality. The home-made soya products that were fermented and germinated also had a significantly ($P < 0{\cdot}05$) higher percentage of dialyzable iron than the others (Table 4). This confirms earlier reports that showed enhancement of iron availability by processes of germination and fermentation (Svanberg & Sandberg, 1989; Moeijopawiro *et al.*, 1987). Prabhavathi and Narasinga Rao (1978) also observed increases in ionizable and soluble iron when green gram was germinated. Bau and Debry (1979), apart from showing losses of phytate during the germination of soyabeans, also demonstrated increased levels of ascorbic acid in these beans (ascorbic acid being a potent enhancer of iron availability). Thus home made soya recipes that incorporate the hulls and involve germination or fermentation are recommended for improving the iron nutritional status of people, particularly the most vulnerable infants and pregnant mothers. The in-vitro dialyzable iron method employed in this study provides a simple screening tool for large samples of food items. Furthermore, it has the advantages of being less expensive, is not time consuming and exhibits low variability of results.

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