ELSEVIER

Food Chemistry 50 (1994) 147-151

0308-8146/94/$7.00

Effects of processing methods on phytic acid level and some constituents in bambara groundnut (*Vigna subterranea*) and pigeon pea (*Cajanus cajan*)

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(Received 28 October 1992; revised version received and accepted 30 June 1993)

The effects of soaking, soaking and dehulling, boiling, roasting, autoclaving and sprouting on the phytic acid content and the protein, carbohydrate, fat, ash, moisture and crude fibre in pigeon pea (*Cajanus cajan*) and bambara groundnut (*Vigna subterranea*) were studied. All the processing methods reduced the phytic acid in the legumes to various extents. Boiling the sprouts had the greatest reducing effect on the phytic acid levels in both legumes as it was significantly reduced by as much as 56% in bambara groundnut and 53% in pigeon pea, respectively ($P < 0{\cdot}05$). Sprouting of the legumes increased their protein content and moisture level significantly ($P < 0{\cdot}05$), while roasting tended to reduce the levels of all the constituents except carbohydrate.

INTRODUCTION

Pigeon peas (*Cajanus cajan*) and bambara groundnuts (*Vigna subterranea*) are important legumes in many tropical and subtropical regions of the world including Nigeria. They provide the major supply of dietary protein and calories. In Nigeria, bambara groundnut and pigeon peas are consumed after appropriate washing, dehulling and boiling or roasting or steaming. They may be eaten alone or mixed with sauce, condiments, spices, and other foods. These legumes, however, contain certain antinutrients which hinder the efficient utilisation, absorption or digestion or nutrients and thus reduce their bioavailability and their nutritional qualities (Liener, 1976).

Phytic acid (myo-inositol-1,2,3,4,5,6,-hexakinase dihydrogen phosphate) is one of the typical antinutrients in legumes. It forms complexes with proteins (protein-phytate complex) (Cheryan, 1980) and chelates essential dietary minerals such as zinc, calcium, magnesium and iron thus decreasing their utilisation (Kratzer, 1965). Thus, the phytic acid in legumes is of significant nutritional interests. However, available evidence indicates that phytic acid in legumes can be removed or reduced by simple processing methods such as soaking, boiling and roasting. A number of studies have been published about the effects of processing methods on phytic acid content in different legumes (Mandal *et al.*, 1972; Hsu *et al.*, 1980; Ologhobo and Fetuga, 1984; Sattar *et al.*, 1988) but there is no published report concerning combinations of processing methods (such as roasting over a time period, sprouting and autoclaving) on levels of phytic acid and the protein, carbohydrate, fat, ash moisture and crude fibre in bambara groundnut or pigeon peas locally grown in Nigeria.

MATERIALS AND METHODS

Materials

Samples of pigeon pea and bambara groundnut were bought at a local market within the Makurdi metropolis and were divided into batches for the various processing treatments.

Methods

The processing methods employed in the study were soaking, soaking and dehulling, boiling, sprouting, autoclaving and roasting

Soaking, soaking and dehulling
Whole seeds, free from dust and other extraneous materials were soaked in water for periods of 6, 12 and 24 (1 : 5 w/v). Following soaking, the seeds were washed twice with ordinary water and dried in a hot-air oven at 70°C to constant weight.

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Table 1. Effect of soaking period on phytic acid in bambara groundnut and pigeon peas[a]

Treatments	Phytate (mg/100 g)	
	Bambara groundnut	Pigeon pea
1. Unsoaked (control)	294 ± 0·003	220 ± 0·002
2. Soaking 6 h	264 ± 0·005 (10)	193 ± 0·003 (12)
3. Soaking 12 h	258 ± 0·003 (19)	187 ± 0·002 (15)
4. Soaking 24 h	235 ± 0·001 (20)	180 ± 0·001 (18)

[a] Values are means ± SD of three determinations (mg/100 g) sample. Figures in parentheses represent loss in phytate expressed as a percentage of control values.

In another treatment, part of the 24th soaked seeds were manually dehulled to remove the seed coat and also dried in a hot-air oven at 70°C to a constant weight.

Boiling
Clean dry seeds were boiled in a volume of distilled water (1 : 3 w/v) until soft (when felt between fingers). The cooked seeds were dried at 70°C to constant weight.

Germination
Seeds presoaked in water (for 24 h) were allowed to germinate in a sterile Petri dish lined with wet filter paper for 3 days (72 h) with frequent watering. The sprouts were dried at 70°C to constant weight in a hot-air oven.

Autoclaving
Clean seeds were autoclaved at a temperature of 121°C for 15 min using the 'Arnold' model autoclave.

Roasting
Clean seeds free from dust and other extraneous materials were roasted at a temperature of 160°C for 15, 30 or 45 min.

Chemical analyses

Phytic acid was analysed using the method of Davies and Reid (1979) which was based on a modified Holt (1955) procedure. Ash, protein, moisture, fat, crude

Table 2. Effects of soaking, dehulling and boiling on phytic acid in bambara groundnut and pigeon pea[a]

Treatment	Phytate (mg/100 g)	
	Bambara groundnut	Pigeon pea
1. Unsoaked (control)	294 ± 0·003	220 ± 0·002
2. Soaking (23 h) and dehulling	232 ± 0·001 (21)	169 ± 0·003 (23)
3. Boiling of unsoaked seeds	252 ± 0·002 (14)	184 ± 0·001 (16)
4. Boiling of soaked seeds	229 ± 0·001 (22)	165 ± 0·002 (25)
5. Boiling of soaked and dehulled seeds	226 ± 0·002 (23)	158 ± 0·001 (28)

[a] Values are means ± SD of three determinations (mg/100 g) sample. Figures in parentheses represent loss in phytate expressed as a percentage of control values. All soakings were for a period of 24 h.

Table 3. Effects of germination, boiling and autoclaving on phytic acid in bambara groundnut and pigeon pea[a]

Treatment	Phytate (mg/100 g)	
	Bambara groundnut	Pigeon pea
1. Control	294 ± 0·003	220 ± 0·002
2. Soaked and sprouted	226 ± 0·002 (23)	154 ± 0·003 (30)
3. Soaked dehulled and sprouted	220 ± 0·003 (25)	147 ± 0·002(33)
4. Boiling of sprouts	130 ± 0·002(56)[b]	103 ± 0·001 (53)[b]
5. Autoclaving of unsoaked seeds	223 ± 0·003 (24)	161 ± 0·002(27)
6. Autoclaving of soaked seeds	199 ± 0·003 (32)	154 ± 0·001(30)
7. Autoclaving of soaked and dehulled seeds	196 ± 0·002 (33)	141 ± 0·003 (36)

[a] Values are means ± SD of three determinations (mg/.100 g). Figures in parentheses represent loss in phytate expressed as a percentage of control values. All soakings were for a period of 24 h.
[b] Reduction significant at 5% level of probability.

fibre and carbohydrate, were determined according to the AOAC (1984) method.

RESULTS AND DISCUSSION

Soaking bambara groundnut and pigeon peas in water resulted in a decrease in the phytic acid and this decrease was progressive with an increase in the soaking period but there was no significant effect of processing on phytate loss ($P > 0{\cdot}05$) (Table 1). The reduction in phytic acid level on soaking was due to the leaching out of phytate ions into the soak water as a result of a concentration gradient (Khckhar & Cauhan, 1986). Similar results were reported when chick pea and black gram were soaked in water by Duhan *et al.* (1988) and other pulses by Ologhobo and Fetuga

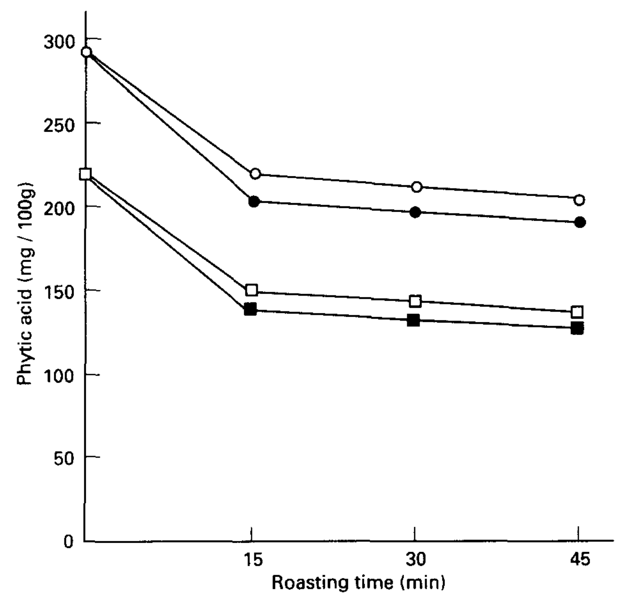

Fig. 1. Effect of roasting time period on phytic acid in bambara groundnut and pigeon peas. (○) Unsoaked bambara groundnut seed, (●) soaked bambara groundnut seed, (□) unsoaked pigeon pea seed, (■) soaked pigeon pea seed.

Table 4. Effects of processing on some constituents in bambara groundnut[a]

Treatment	Constituents expressed in (g/100 g wet weight)					
	Protein	Ash	Fat	Moisture	Crude fibre	Carbohydrate
Control	17·2 ± 0·02	3·29 ± 0·3	5·0 ± 1·05	7·3 ± 0·56	3·45 ± 0·08	652·8 ± 0·9
Soaking	18·1 ± 0·02 (6)	3·20 ± 0·01 (3)	4·6 ± 1·03 (8)	12·3 ± 0·02 (68)	3·48 ± 0·03 (0·8)	58·3 ± 0·4 (17)
Sprouting	23·0 ± 0·02 (34)	3·79 ± 0·3 (15)	3·93 ± 0·21 (21)	13·1 ± 0·01 (79)[b]	3·62 ± 0·04 (5)	67·1 ± 0·2 (18)
Roasting						
15 min	16·7 ± 0·03 (3)	3·23 ± 0·01 (2)	3·45 ± 0·01 (31)	5·39 ± 0·12 (27)	3·02 ± 0·07 (12)	66·3 ± 0·4 (6)
30 min	14·7 ± 0·42 (14)	3·20 ± 0 (3)	3·37 ± 0·02 (38)	4·56 ± 0·06 (37)	2·65 ± 0·27 (24)	70·2 ± 0·7 (11)
45 min	14·1 ± 0·14 (12)	2·84 ± 0·04 (3)	3·30 ± 0·04 (34)	3·04 ± 0·32 (53)	2·34 ± 0·12 (32)	72·1 ± 0·2 (16)
Autoclaving		3·19 ± 0·02 (3)	3·22 ± 0·22 (36)	6·69 ± 0·24 (8)	3·25 ± 0·24 (6)	68·4 ± 0·4 (9)

[a] Values are means ± SD of three determinations. Figures in parentheses represent loss or gain in constituents expressed as a percentage of control value.
[b] Significant at 5% level of probability.

(1984). The non-significant difference in decline of phytate content between the undehulled (20%) and dehulled and soaked seeds (21%) in bambara groundnut suggests that only a small amount of total phytate may be located in its seed coat.

In this study, boiling of the legumes without prior soaking showed a decrease in the phytic acid content (Table 2). This decrease on boiling may be due to the formation of insoluble complexes between phytate and other components (Kumar *et al.*, 1978). However, boiling of soaked seeds showed a further lowering of the phytic acid content which agrees with the findings of Kataria *et al.* (1988) who attributed such a reduction in the antinutrient to leaching into the soak water. Table 3 shows that sprouting of the seeds considerably reduced the phytic acid level in both legumes which may be due to the high phytase activity during sprouting of the grain legumes (Mandal *et al.*, 1972; Eskin & Wiebe, 1983).

However, the loss of phytic acid observed on sprouting was less than that reported for sprouted black gram and dry beans in earlier studies (Reddy *et al.*, 1978; Tebekhua & Luh, 1980). Boiling of the sprouts significantly lowered the phytic acid content in both legumes ($P < 0{\cdot}05$), which may be due to a combination of the following factors: the initial loss on soaking, increased phytase activity on sprouting and the heat-treatment applied to the seeds on boiling. Roasting (Fig. 1) and autoclaving treatments reduced the phytic acid in both legumes. It is reasonable to assume that roasting and autoclaving which are applications of heat treatment could have a reducing effect on the phytate level of the legumes. A significant decrease was observed ($P < 0{\cdot}05$) when soaked seeds were roasted for 45 min. However, greater losses of the phytic acid were observed in the pigeon pea than the bambara groundnut.

Protein content in both legumes increased marginally on soaking, with a higher increase observed in bambara groundnut (Tables 4 and 5). The increase may be due to the dissolution of proteins covalently bonded to starch in the cooking medium (Scatter *et al.*, 1988). A significant increase of the moisture was observed in both legumes ($P < 0{\cdot}05$) which was due to imbibition of water into the legume by simple diffusion. The ash and carbohydrate levels were also observed to decrease which agrees with the findings of Albrecht *et al.* (1966) and Konn (1979), who attributed such a decrease to the loss of solid materials on soaking. Sprouting increased the protein content and significantly increased the moisture content ($P < 0{\cdot}05$) in both legumes. This increase in protein seeds is ambiguous as this increase may be due to increase in the non-protein nitrogen (El-Shimi *et al.*, 1984). The protein content of legumes has been shown to generally increase during germination (Kylen & McCready, 1975; Hsu *et al.*, 1980). The decrease in fat content of the legumes on sprouting the

Table 5. Effects of processing on some constituents in pigeon pea[a]

Treatment	Constituents expressed in (g/100 g wet weight)					
	Protein	Ash	Fat	Moisture	Crude fibre	Carbohydrate
Control	20·0 ± 0·27	3·62 ± 0·04	1·51 ± 0·23	11·05 ± 0	4·27 ± 0·15	59·4 ± 0·2
Soaking	20·3 ± 0·4 (3)	3·59 ± 0·3 (1)	1·50 ± 0·3 (1)	16·10 ± 0·3(45)	4·27 ± 0·3	54·2 ± 0·8 (9)
Sprouting	21·3 ± 0·5 (7)	3·65 ± 0·05 (1)	0·85 ± 0·05 (43)	4·54 ± 0·01 (68)[b]	4·54 ± 0·1 (6)	61·0 ± 0·4 (14)
Roasting						
15 min	12·2 ± 0·02 (37)	3·26 ± 0·07 (10)	1·18 ± 0·1 (21)	10·1 ± 0·03 (7)	2·06 ± 0·03 (52)	73·2 ± 0·01 (23)
30 min	9·32 ± 0·2 (53)	3·01 ± 0·08 (17)	0·78 ± 0·3 (43)	3·78 ± 0 (48)	2·00 ± 0002 (53)	81·2 ± 0·5 (36)
45 min	9·17 ± 0·05 (31)	3 ± 0·03 (17)	0·78 ± 0·02 (38)	3·50 ± 0·38 (7)	1·99 ± 0·3 (2)	81·6 ± 0·4 (16)
Autoclaving	13·7 ± 0·02 (31)	3·10 ± 0·1 (17)	0·93 ± 0·06 (38)	10·29 ± 0·16 (7)	4·19 ± 0·3 (2)	69·1 ± 2·7 (16)

[a] Values are means ± SD of three determinations. Figures in parentheses represent loss or gain in constituents expressed as percentage of control values.
[b] Significant at 5% level of probability.

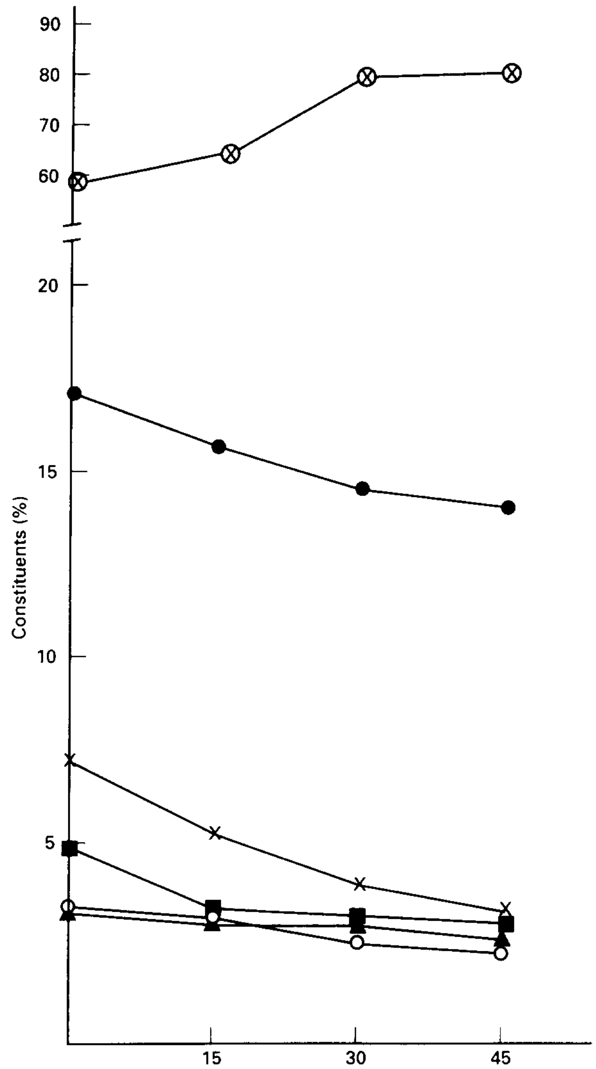

Fig. 2. Effect of roasting time period on some constituents in bambara groundnut. (●) Protein, (▲) ash, (■) fat, (×) moisture, (○) crude fibre, (⊗) carbohydrate.

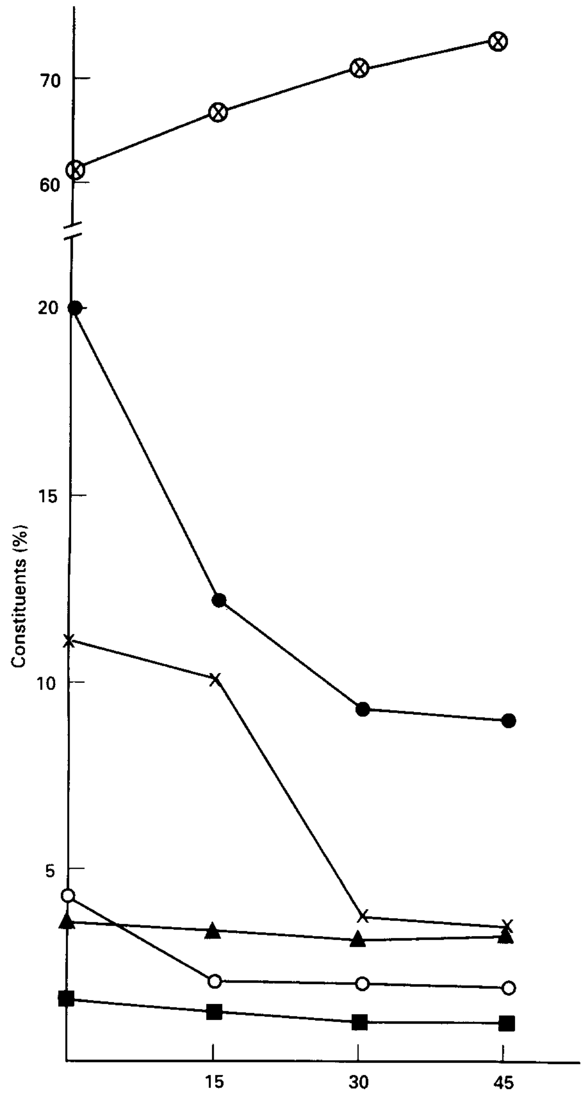

Fig. 3. Effect of roasting time period on some constituents in pigeon peas. (●) Protein, (▲) ash, (■) fat, (×) moisture, (○) crude fibre, (⊗) carbohydrate.

seeds (Tables 4 and 5) was due in part to the breakdown of fat into glycerol and fatty acid and its subsequent hydrolysis for energy production. The depletion of fats in germinating legumes has been reported by Kylen and McCready (1975) for lentils, mung beans and soyabeans. Roasting reduced the moisture level in the two legumes which is not unexpected as a result of the heat treatment which caused the loss of moisture in the legumes seeds (Kabirullah *et al.*, 1977). The decrease in fat content in both legumes on roasting is probably due to the volatilisation of fat as well as melting of fat during this heat treatment.

In the two legumes, most of the reduction of constituents such as fat and crude fibre occurred after the first 15 min of roasting while, for the protein and moisture content, this occurred after 30 min of roasting at a temperature of 160°C. The carbohydrate increased with increase in the roasting temperature and seemed to level off after 30 min of roasting. (Figs 2 and 3).

In conclusion, it is suggested that these legumes, prior to consumption, should be soaked and dehulled before cooking or sprouted prior to cooking in order to substantially reduce their phytic acid contents and increase their nutritional quality.

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