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Content of phytic acid and HCl-extractability of calcium, phosphorus and iron as affected by various domestic processing and cooking methods

Aarti Duhan, Neelam Khetarpaul*, Saroj Bishnoi

Department of Foods and Nutrition, CCS Haryana Agricultural University, Hisar-125004, India

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Abstract

ICPL-87, the high yielding cultivar of pigeon pea (*Cajanus cajan*) released by ICRISAT (International Crop Research Institute for Semi-Arid Tropics), India was subjected to various domestic processing and cooking methods, i.e. soaking (6, 12, 18 h, 30°C), soaking (12 h) and dehulling, ordinary as well as pressure cooking and germination (24, 36 and 48 h, 30°C). The unprocessed seeds of this variety contained considerable amounts of phytic acid, (857 mg per 100 g). This was reduced significantly ($P < 0.05$) by 6–28%, 30%, 4–32%, 4–36%, 35–45% in soaked, soaked-dehulled, ordinary as well as pressure cooked and germinated seeds, respectively. Except for soaking and dehulling, the remaining processing and cooking methods did not lower the contents of total calcium, phosphorus and iron. HCl-extractability of these dietary essential minerals, an index of their bioavailability, was enhanced significantly when the pigeon pea seeds were processed and cooked, possibly due to reduction in phytate content, which is known to chelate the minerals. A significant and negative correlation between the phytic acid and HCl-extractability of minerals further strengthens these findings.

Keywords: Pigeon pea; Phytic acid; HCl-extractability; Calcium; Phosphorus; Iron

1. Introduction

Pigeon pea is one of the important crops and ranks fifth in importance among edible legumes of the world. India alone, contributes over 90% of the world pigeon pea production. The contents of crude protein, fat and ash in some high-yielding cultivars of pigeon pea varied from 22.8–25.5; 1.3–2.1 and 2.8–3.5 g/100 g, respectively. Total soluble sugars, reducing sugars, non-reducing sugars, starch and total carbohydrates in different cultivars of pigeon pea ranged from 6.71–6.92 g, 1.21–1.28 mg, 5.43–5.71 g, 51.23–51.60 g and 57.4–58.1 g/100 g, respectively on a dry matter basis (Duhan, Khetarpaul & Bishnoi, 1995). Besides these nutrients, pigeon pea cultivars also contained antinutrients, i.e. phytic acid (857–917 mg/100 g), polyphenols (1075–1328 mg/100 g), saponins (2164–3494 mg/100 g) and trypsin inhibitor activity (1007–1082 TIU/g), respectively, which are known to limit the utilization of this legume for human nutrition.

Phytic acid [myoinositol 1,2,3,4,5,6-hexakis (dihydrogen phosphate)], present in most plant food stuffs (Yadav and Khetarpaul, 1994) as the phytate salt or a complex with protein, chelates with certain metal ions (such as calcium, zinc, copper and iron) to form insoluble protein–mineral–phytate complexes. These complexes fail to break down readily and make the minerals, especially divalent cations, unavailable. Hence, it is of paramount importance to lower the phytate content of pigeon pea through any of the processing and cooking methods used in the household, so as to improve its nutritional value.

Legume grains are generally processed before consumption, depending upon cultural and taste preferences. In India, the most commonly used domestic methods for processing of legumes include soaking for different time periods, dehulling of soaked seeds, ordinary and pressure cooking and germination and these have been reported to be beneficial for enhancing the nutritive value of some food legumes, including chick pea, peas, moth bean, mung bean and rice bean. Such information is also very important for pigeon pea. Therefore, this study was planned to find the effects of

* Corresponding author. Fax: +91-1662-33000.
E-mail address: khetarpaul@vsnl.com (N. Khetarpaul).

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domestic processing and cooking methods on contents of antinutrients and HCl-extractability of calcium, phosphorus and iron of pigeon pea.

2. Materials and methods

2.1. Materials

The seeds of ICPL-87, which is a variety of pigeon pea (*Cajanus cajan*) were procured from the ICRISAT (International Crop Research Institute for Semi-Arid Tropics) centre, Hisar, India. The selection of this variety was done on the basis of high yield and early maturity.

The seeds were cleaned of dust, cracked and broken seeds and other foreign material prior to domestic processing and cooking treatments. Raw seeds were powdered (0.05-mm sieve) in an electric grinder (Cyclotec, M/s Tecator, Hoganas, Sweden), packed in air-tight containers and were used as control. The experimental samples, for ordinary and pressure cooking, included unsoaked, soaked and soaked-dehulled. Therefore, the unsoaked seeds were either cooked ordinarily or in a pressure cooker where as the control samples were not given any kind of treatment, i.e. soaking, cooking or germination. The processing and cooking treatments were done in triplicate.

2.2. Processing and cooking methods

2.2.1. Soaking

Seeds were soaked in double-distilled water for 6, 12 and 18 h at 30°C. Seed to water ratio used was 1:5 w/v. The soaked seeds were washed and rinsed with double-distilled water.

For further treatments, i.e. dehulling, ordinary cooking, pressure cooking and germination, the seeds were soaked for 12 h as it is general pratice in Indian households to soak legume seeds overnight prior to processing and cooking.

2.2.2. Soaking and dehulling

After soaking, the seeds overnight (12 h), hulls were removed manually.

2.2.3. Ordinary cooking

The unsoaked, soaked (12 h) and soaked-dehulled seeds were cooked in crude fibre beakers. The amount of water used for ordinary cooking was three times the weight of the seeds. Seeds were cooked until soft as felt between the fingers.

2.2.4. Pressure cooking

Pressure cooking of unsoaked, soaked (12 h) and soaked-dehulled seeds was done at 1.5 kg/cm^2. Water used for pressure cooking was twice the weight of seeds.

2.2.5. Germination

The soaked seeds (12 h) were washed and rinsed with distilled water. The seeds were rolled in germination paper kept in an incubator at 30°C for 24, 36 and 48 h.

2.2.6. Preparation of processed samples

All the processed seeds were dried in the hot air oven kept at 60°C to a constant weight, ground in an electric grinder (Cyclotec, M/s Tecator, Hoganas, Sweden) using a 0.5-mm sieve size, and packed in air-tight containers for further chemical analysis.

2.3. Chemical analysis

Phytic acid content was determined by the method of Davies and Reid (1979).

2.3.1. Total minerals

The control and processed legume samples were wet acid-digested with diacid, i.e. a nitric acid and perchloric acid mixture (HNO_3:$HClO_4$,5:1, v/v) in the digestion chamber. The digested samples were dissolved in double-distilled water and filtered (Whatman No. 42). The filtrate was made to 50 ml with double distilled water and was used for determination of total calcium, phosphorus and iron.

Calcium in the digested sample was determined by a titration method (Vogel, 1962). Phosphorus was determined colorimetrically by the method of Chen, Tosibara, and Warner (1956). Phytate phosphorus was derived by using the following (Reddy, Sathe, & Salunkhe, 1982).

$$\text{Phytate phosphorus (mg)} = \frac{A \times 28.18}{100}$$

where A is the phytate content (mg)

Non-phytate phosphorus was calculated as a difference between the total phosphorus and phytate phosphorus.

2.3.2. Trace minerals

Trace mineral iron in acid-digested samples was determined by the Atomic Absorption Spectrophotometer, 2380, Perkin-Elmer (USA) in the Department of Foods and Nutrition, CCS Haryana Agricultural University, Hisar according to the method of Lindsey and Norwell (1969).

2.3.3. HCl-Extractable minerals

The minerals in the samples were extracted with 0.03 N HCl by shaking the contents at 37°C for 3 h. The clear extract obtained after filtration with Whatman No. 42 filter paper was oven-dried at 100°C and wet acid-digested. The amounts of the HCl-extractable calcium, phosphorus and iron in the digested samples were determined by the methods just described for estimation of total minerals:

$$\text{Mineral extractability \%} = \frac{\text{Mineral extractability in 0.03 N HCl}}{\text{Total minerals}} \times 100$$

2.4. Statistical analysis

The data were subjected to statistical analysis of variance in a complete randomized design and correlation coefficients were derived according to standard methods (Panse and Sukhatme, 1961).

3. Results and discussion

3.1. Phytic acid

ICPL-87 variety contained 857 mg phytic acid per 100 g (Table 1). Various domestic processing and cooking methods reduced the content of this antinutrient to varying extents. Soaking for different time periods could lower the level of this antinutrient to the extent of 6–28 % over the control value. Longer the periods of soaking, caused greater losses in the phytic acid content. The cumulative effect of soaking and dehulling were more pronounced than soaking alone for lowering the phytic acid content. The combined effect of 12 h soaking and dehulling on phytic acid reduction was significantly ($P<0.05$) higher than that of 18 h soaking alone. Moreover, legumes have to be cooked prior to their consumption as they are not acceptable to the human palate in raw form and, also, cooking improved the digestibility of carbohydrates and proteins. The loss in phytates during soaking of pigeon pea may be due to leaching of phytate ions into the soaking water under the influence of a concentration gradient (difference in chemical potential) which governs the rate of diffusion. Similar results for reduction in phytic acid in the soaked as well as soaked-dehulled peas have been reported earlier (Bishnoi, Khetarpaul, & Yadav 1994).

Ordinary cooking of unsoaked, soaked and soaked-dehulled pigeon pea seeds brought about a significant decrease in phytic acid content when compared to the control (Table 1). A reduction in phytic acid content was noticed after ordinary cooking of unsoaked seeds but this loss appeared to be less than that in seeds, which were cooked after soaking or soaking and dehulling. The per cent loss in phytic acid content of soaked and cooked seeds was 15 and it was more than double when these seeds were soaked, dehulled and cooked, i.e. 32. There was not a significant ($P<0.05$) difference between the

Table 1
Effect of domestic processing and cooking methods on phytic acid (mg/100 g), phytate phosphorus (mg) and percentage of total phosphorus (%) in pigeon pea (on dry matter basis)[a]

Treatment	Phytic acid	Total phosphorus	Phytate phosphorus		Phytate phosphorus		Phosphorus extractability
			Total	% of total phosphorus	Total	% of total phosphorus	
Control soaking	857±8	468±0.2	242±0.9	51.5±0.03	227±0.4	48.4±0.03	34.4±0.4
6 h	804±5 (−6)	456±0.1 (−3)	227±0.8	49.6±0.42	229±0.5	50.3±0.42	35.6±0.6 (+3)
12 h	730±9 (−15)	446±0.1 (−5)	206±0.8	46.1±0.37	240±0.6	53.88±0.37	36.6±0.6 (+6)
18 h	620±7 (−28)	440.4±0.4 (−6)	195±0.4	39.6±0.30	246±0.30	60.33±0.30	37.4±0.4 (+9)
Soaking and dehulling	600±8 (−30)	420±0.5 (−10)	169±0.5	40.2±0.57	251±0.4	59.76±0.57	38.0±0.1 (+10)
Ordinary cooking							
Unsoaked	822±5 (−4)	468±0.2	232±0.6	49.9±0.50	237±.0.8	50.5±0.50	38.3±0.2 (+11)
Soaked	725±7 (−15)	446±0.1 (−5)	204±0.5	45.8±0.42	242±0.9	54.2±0.42	41.3±0.2 (+20)
Soaked and dehulled	580±7 (−32)	420±0.5 (−10)	163±0.4	38.9±0.30	257±0.7	61.1±0.30	46.3±0.2 (+35)
Pressure cooking							
Unsoaked	820±16 (−4)	468±0.2	203±0.8	43.3±0.25	265±0.4	56.67±0.25	40.4±0.4 (+17)
Soaked	720±18 (−16)	446±0.1 (−5)	203±0.5	45.4±0.30	243±0.4	54.5±0.30	43.4±0.4 (+26)
Soaked and dehulled	550±15 (−36)	420±0.5 (−10)	155±0.4	36.8±0.37	265±0.4	63.11±0.37	50.3±0.2 (+46)
Germination							
24 h	560±7 (−35)	446±0.1 (−5)	159±0.4	35.3±0.20	287±0.8	64.62±0.20	43.4±0.4 (+26)
36 h	520±9 (−39)	446±0.1 (−5)	146.53±0.4	32.8±0.21	299±0.5	67.1±0.21	50.3±0.2 (+46)
48 h	470±6 (−45)	446±0.1 (−5)	132±0.4	29.6±0.11	314±0.4	70.3±0.11	64.4±0.4 (+87)
S.E. (m)	±4.34	±4.38	±0.39	±0.59	±0.41	±0.09	±0.23
CD ($P<0.05$)	13.09	13.49	1.21	1.81	1.19	0.29	0.70

[a] Values are means ± S.D. of three independent determinations; figures in parentheses indicate per cent decrease (−) or increase (+) over control values.

phytic acid contents of pigeon pea seeds soaked for 12 h and those soaked (12 h) as well as cooked ordinarily.

On pressure cooking of unsoaked seeds, there was a significant reduction in phytic acid content (Table 1). Pressure cooking of soaked, as well as soaked-dehulled seeds, caused a greater loss than pressure cooking of unsoaked seeds. The phytic acid content of ICPL-87 variety was reduced by 4, 16 and 36% when unsoaked, soaked and soaked-dehulled seeds were pressure cooked, respectively. According to de Boland, Garner, and O'dell (1975), the differences in the loss of phytic acid contents during cooking could probably be explained on the basis that phytase activity at a temperature of 40–55°C may degrade inositol hexaphosphate to the pentaphosphate or lower molecular weight forms. Kumar, Venkataraman, Jaya, and Krishnamurthy (1978) observed that phytic acid content decreased because insoluble complexes between phytate and other components were formed during cooking.

Germination also resulted in a considerable loss of phytic acid. As the period of germination was prolonged, a significant and successive reduction in this antinutrient was witnessed; after 48 h germination a loss of up to 45% was noticed (Table 1). Loss of phytic acid during germination may be due to hydrolytic activity of phytase reported to be present in various plant foods (Lolas & Markakis, 1975).

3.2. Phytate, non-phytate and extractable phosphorus

Fifty two percent of the total phosphorus was present as phytate phosphorus in the unprocessed pigeon pea seeds. Various domestic and cooking methods resulted in a significant decrease with a corresponding marked increase in non-phytate phosphorus and HCl-extractable phosphorus (Table 1). Germination was found to be the best processing method, followed by pressure cooking and ordinary cooking of soaked-dehulled seeds for reducing the content of phytate phosphorus and improving the HCl-extractability of phosphorus. Cleavage of phosphorus from the phytic acid may explain the increased level of non-phytate phosphorus and higher HCl-extractability of phosphorus in the processed and cooked pigeon pea seeds (Bishnoi & Khetarpaul, 1995).

3.3. Total and HCl-extractability of calcium, phosphorus and iron

3.3.1. Total minerals

With an increase in the period of soaking, a loss in the content of total calcium, phosphorus and iron was observed to varying extents (Tables 1 and 2). Dehulling of soaked seeds caused a further significant reduction in all three minerals studied. The loss in the mineral content

Table 2
Effect of domestic processing and cooking methods on total mineral contents (mg/100 g) and their extractability (%) in pigeon pea (on dry matter basis)[a]

Treatment	Minerals			
	Calcium		Iron	
	Total	Extractability	Total	Extractability
Control soaking	216±0.4	51.3±0.90	10.3±0.07	37.2±0.03
6 h	205±0.5 (−5)	52.2±0.78 (+2)	10.1±0.51 (−2)	37.4±0.13 (+4)
12 h	199±0.3 (−8)	53.2±0.79 (+4)	10.0±0.65 (−3)	40.4±0.13 (+8)
18 h	193±0.1 (−11)	54.2±0.75 (+6)	10.0±0.51 (−3)	42.6±0.23 (+14)
Soaking and dehulling	162±0.4 (−25)	61.3±0.86 (+19)	9.8±0.09 (−5)	46.6±0.48 (+25)
Ordinary cooking				
Unsoaked	216±0.4	55.2±0.78 (+8)	10.3±0.07	44.0±0.40 (+18)
Soaked	199±0.3 (−8)	58.2±0.90 (+13)	10.0±0.07 (−3)	49.7±0.47 (+35)
Soaked and dehulled	162±0.4 (−25)	60.2±0.1 (−17)	9.8±0.07 (−5)	52.8±0.53 (+42)
Pressure cooking				
Unsoaked	216±0.4	56.2±0.78 (+10)	10.3±0.07	47.0±0.03 (+26)
Soaked	199±0.3 (−8)	58.3±0.78 (+14)	10.0±0.07 (−3)	51.3±0.03 (+38)
Soaked and dehulled	162±0.4 (−25)	62.0±0.78 (+21)	9.8±0.07 (−5)	55.8±0.21 (+50)
Germination				
24 h	199±0.3 (−8)	61.3±0.5 (+19)	10.0±0.07 (−3)	46.6±0.42 (+25)
36 h	199±0.3 (−8)	64.3±0.5 (+25)	10.0±0.07 (−3)	48.1±0.50 (+29)
48 h	199±0.3 (−8)	65.3±0.5 (+27)	10.0±0.07 (−3)	53.0±0.30 (+42)
S.E.(m)	±0.36	±0.48	±0.11	±0.15
CD($P<0.05$)	1.08	1.43	0.32	0.45

[a] Values are means ± S.D. of three independent determinations; figures in parentheses indicate per cent decrease (−) or increase (+) over control values.

Table 3
Correlation coefficient of phytic acid with HCl-extractability of calcium, phosphorus and iron

Treatment	HCl-extractability of minerals		
	Calcium	Phosphorus	Iron
6 h soaking	−0.2312	−0.2930	−0.3940
12 h soaking	−0.2930	−0.3240	−0.4251*
18 h soaking	−0.3137	−0.3347	−0.4359*
Soaked (12 h), dehulled	−0.3296	−0.4183*	−0.5190*
Unsoaked and cooked	−0.4178*	−0.4919*	−0.5923**
Soaked (12 h) and cooked	−0.4903*	−0.5459**	−0.6462**
Soaked (12 h), dehulled and cooked	−0.5455**	−0.4310*	−0.5330*
Unsoaked and pressure cooked	−0.4296*	−0.5213**	−0.6223**
Soaked (12 h) and pressure cooked	−0.5183**	−0.6497**	−0.7470**
Soaked (12 h), dehulled and pressure cooked	−0.6457**	−0.6614**	−0.7634**
24 h germination	−0.4923*	−0.5463**	−0.6465**
36 h germination	−0.5190**	−0.6527**	−0.7530**
48 h germination	−0.6517**	−0.6724**	−0.7726**

*Significant at 5% level
**Significant at 1% level

on soaking may be attributed to leaching of these minerals into the soaking medium (Kumar, Venkataraman, Jaya, & Krishnamurthy 1978). During dehulling, minerals present in the hulls might have been lost. Cooking of unsoaked seeds caused no loss whereas significant loss was noticed when soaked dehulled seeds were cooked. It seems that no loss of minerals occurred during cooking but some of the overall loss, was due to the fact that the seeds prior to cooking were soaked and dehulled. Germination itself, too, had no effect on loss of total contents of calcium, phosphorus and iron. As the period of germination increased, the percent loss of all the minerals was constant. Hence, the loss was not due to germination, but again it was due to soaking (12 h), done prior to germination. The values are consistent with those reported earlier (Bishnoi and Khetarpaul, 1995, 1996, 1997).

3.3.2. Extractable minerals

With an increase in the period of soaking, the extractability of all the minerals studied increased significantly ($P < 0.05$). Almost a three-fold increase was found in the extractability of these minerals after 18 h soaking. Soaking, followed by dehulling, further caused an increase in the HCl-extractability of these minerals.

Ordinary cooking, as well as pressure cooking, could enhance the extractability of minerals of unsoaked pigeon pea seeds but this was obviously less than that of soaked and soaked-dehulled seeds. Moist heating i.e. pressure cooking could improve the extractability of minerals to a greater extent than ordinary cooking (Tables 1 and 2).

Increase in the germination period significantly affected the extractability of calcium, phosphorus and iron. After a 48 h germination, extractabilities of calcium (27%) and phosphorus (87%) were found to be maximum when compared with that in the rest of the processed and cooked pigeon pea seeds. As the divalent cations, including calcium and iron, are generally present in association with the phytic acid in plant foods, this may be the reason for their lower extractability. Decrease in the level of phytic acid by various domestic and processing methods i.e. soaking, dehulling, ordinary cooking, pressure cooking and germination as reported by previous workers (Bishnoi et al., 1994; Jood, Bishnoi, & Sehgal, 1998; Kataria, Chauhan, & Punia, 1989) as well as the present study, may possibly release these metallic ions in the free form and account for their increased HCl-extractability. The antinutrient, i.e. phytic acid, in the processed pigeon pea was found to have a negative correlation with extractability of calcium, phosphorus and iron (Table 3), which underlines the role of phytic acid in lowering the extractability of divalent cations in plant foods.

4. Conclusion

Overall, all the different processing and cooking methods were found to be beneficial for lowering the phytic acid content and improving the bioavailability of dietary essential minerals in pigeon pea. Among all methods, germination was found to be the best method, followed by pressure cooking of soaked-dehulled, ordinary cooking of soaked-dehulled, soaking–dehulling and soaking alone of the pigeon peas seeds. Hence, for proper utilization of pigeon pea, especially in developing countries, these simple and economic household processing and cooking methods should be followed, as they not only save time, energy and fuel consumption but also enhance the nutritional quality of the legumes by lowering the content of antinutrients and increasing the bioavailability of minerals.

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