Pak J Sci Ind Res 2002 45 (1) 41-45

Effect of Different Soaking and Cooking Methods on Physical Characteristics, Phytic Acid Content and Protein Digestibility of Red Kidney Beans

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(Received 1 February 2000; accepted 10 February 2001)

Effect of different soaking and cooking methods on some physical characteristics, phytic acid content and protein digestibility of red kidney beans is reported. Soaking of kidney beans in 4% acetic acid solution gave rise to lower hydration capacity, hydration index, swelling capacity and cooking time than soaking in tap water. Phytic acid contents of red kidney beans were reduced to various extents on soaking in different solutions at 30°C and 100°C. However, soaking in acetic acid solution with or without sodium chloride was the most efficient method for reducing phytic acid. Phytic acid was further reduced on cooking by different ways. Cooking in a pressure cooker caused maximum reduction in phytic acid contents. Ordinary and microwave cooking also showed pronounced effect on reduction of phytic acid. Reduction in the level of phytic acid was not found responsible for improving the protein digestibility of red kidney beans.

Key words: Red kidney beans, Phytic acid, Protein digestibility, Reduction, Soaking, Cooking.

Introduction

Dry beans are a good source of proteins, minerals and vitamins but the presence of several antinutrients limit their utilization in human diet (Morrow 1991).Phytic acid is the main antinutrient which adversely affects the nutritional quality of beans. There are numerous studies which show that phytic acid affects the bioavailability of essential minerals and inhibits the activities of amylolytic enzymes (Nolan and Duffin 1987). In addition, complex formation of phytic acid with proteins may inhibit the enzymatic digestion of proteins (Singh and Krikorian 1982). In view of the deleterious effects of phytic acid, it is necessary to reduce phytic acid before consumption in order to improve nutritional quality of the dry beans. It has been observed by earlier workers that soaking in water reduced the amount of phytic acid in the beans to some extent (Tabekhia and Luh 1980; Marfo *et al* 1990). Reduction in phytic acid content of some edible legumes during germination and cooking has also been reported in the literature (Ologhobo and Fetuga 1984; Khokhar and Chauhan 1986). Some changes in physical characteristics of certain beans are also associated with soaking and cooking processes (Phirke *et al* 1982; Attia *et al* 1994).

Soaking of dry beans in simple water and salt solution is a common practice to soften texture and hasten the cooking process. Therefore, red kidney beans were soaked in different types of solutions at 30°C and 100°C for reducing phytic acid before cooking during this study. This paper reports the effect of different soaking and cooking methods on the phytic acid content and protein digestibility of red kidney beans. Physical characterics of soaked kidney beans were also studied.

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Materials and Methods

Red and white kidney beans were obtained from Ayub Agricultural Research Institute, Resalewala, Faisalabad (Pakistan). These beans were grown under similar soil and agroclimatic conditions. Beans were cleaned to remove broken seeds, dust and other foreign materials and then subjected to various soaking treatments prior to cooking.

Soaking treatments. The beans were soaked in tap water, 2.5% sodium chloride, 4% acetic acid solution and mixture of 4% acetic acid and 2.5% sodium chloride solution at 30° and 100°C for different time periods. The beans to water ratio was 1: 5. The soaked beans were rinsed twice with distilled water and then dried in hot air oven at 60°C for 24 h. Presoaked kidney beans (without drying) were cooked by different methods as given below:

Cooking Treatments. a) Ordinary cooking: Presoaked kidney beans were put in a round bottom flask fitted with a reflux condenser. The water (four times the weight of dry beans)

was added and the samples were boiled on a hot plate for 30 min.

b) Pressure cooking. Presoaked kidney beans were placed in one litre beakers containing tap water (for time the weight of dry beans). Top of the beakers was covered with aluminium foil and cooked in a pressure cooker at 15 lbs $inch^{-2}$ pressure for 5 min.

c) Microwave cooking. Presoaked kidney beans were placed in a covered glass pot containing tap water (four time the weight of dry beans) which was then heated in a domestic microwave oven (Panasonic 115 V, 550 Cooking power) at 250°C for 3 min.

After each cooking, excess of water was drained off and samples were dried at 60°C in hot air oven for 24 h.

Chemical analysis. Samples of kidney beans were ground in an electric mill (Braun type 4248) to pass through a 0.250 mm screen. Proximate composition of the ground samples, for moisture, ash, protein, fat and fibre was estimated by standard methods of AOAC (1990). Phytic acid was extracted in 0.5 M nitric acid by shaking at room temperature for 3 h and determined calorimetrically by the method described by Davies and Reid (1979). *In vitro* protein digestibility was estimated after digestion with pepsin HCl solution at 37.5°C for 24 h (Price *et al* 1979). Hydration capacity, hydration index and swelling capacity of the kidney beans soaked in different solutions were estimated by the method of Onayemi *et al* (1986) whereas cooking time of soaked and unsoaked kidney beans was determined by the method described by Singh *et al* (1991). Data of soaked and cooked beans was recorded and standard deviation (SD) was calculated according to steel and Torrie method (1980). Differences between treatments at 5% level were considered significant.

Results and Discussion

Table 1 indicates that chemical composition of red and white kidney beans were almost the same. However, the amount of phytic acid in red kidney beans was higher (10.84 g kg^{-1}) than white kidney beans (9.29 g kg^{-1}) whereas the protein digestibility of red kidney beans was found comparatively less (387.80 g kg^{-1}) than those of white kidney beans (412.0 g kg^{-1}). Variation in protein digestibility of these two cultivars were found to be significant ($P<0.05$) whereas non significant difference was observed in case of phytic acid content.

Nutritional quality especially protein digestibility of legumes generally depends upon the amount of antinutrient. In the present study, the amount of phytic acid was comparatively higher in red kidney beans than white kidney beans. Therefore, red kidney beans were selected for further studies in order to improve its nutritional value.

Effect of soaking of physical characteristics and cooking time. Data presented in Table 2 indicates that physical characteristics of red kidney beans were changed to some extent on soaking in different salt solutions.

Hydration capacity, hydration index and swelling capacity values of beans soaked in simple water and sodium chloride solution were significantly ($P<0.05$) higher than the kidney beans soaked in acetic acid solution with or without sodium chloride. Cooking time of the kidney beans soaked in acetic acid solution with or without sodium chloride remarkably reduced as compared with the beans soaked in tap water and neutral sodium chloride solution. It seems that hardness of the beans was decreased due to absorption of sufficient water from the soaking solution and caused reduction in cooking time to various extent depending upon the nature of the soaking solution and cooking methods. It is also possible that acidic solutions also affected the cell membranes of the beans and reduced the cooking time to great extent. Many other workers also reported reduction in cooking time due to soaking of various legumes in different types of solutions (Onayemi *et al* 1986; Phirke *et al* 1982).

Effect of soaking on phytic acid contents. Data presented in Table 3 indicates that considerable amount of phytic acid was removed from red kidney beans by soaking in different solutions at 30°C and 100°C for different periods. However, removal of phytic acid was found to be minimum in case of tap water soaking process. Soaking of red kidney beans in tap water at 30° and 100°C for 4 h removed 6.91 and 15.49% phytic acid respectively whereas about 9.50% at 30°C and 18.08% at 100°C, phytic acid was removed as a result of soaking in neutral sodium chloride solution for 4 h. Removal of phytic acid during these soaking processes at 100°C indicated easy penetration of water into the beans which helped

Table 1
Chemical composition, phytic acid contents and protein digestibility of raw kidney beans*

Parameters (g Kg^{-1})	Red kidney beans	White kidney beans
Moisture	38.8 ± (1.7)	39.40 ± (2.1)
Crude Protein	239.0 ± (2.6)	237.70 ± (2.3)
Ash (Minerals)	40.50 ± (2.0)	42.00 ± (1.8)
Crude Fat	24.50 ± (1.5)	23.80 ± (1.2)
Crude fibre	48.00 ± (1.9)	47.30 ± (1.8)
Phytic Acid	10.84 ± (1.6)	9.29 ± (1.6)
Protein digestibility before cooking	387.80	412.0

Mean ± SD triplicate samples.

to leach out greater amount of this anti-nutrient from the material. Duhan *et al* (1989) found that substantial amount of phytic acid was removed from chick pea and black gram during water soaking process.

Soaking in acetic acid solution alone or in combination with sodium chloride resulted in better removal of phytic acid from red kidney beans than tap water and sodium chloride solution. Soaking of kidney beans in 4% acetic acid solution at 30° and 100°C for 4 h, resulted in reducing phytic acid by 14.94 and 25.46% respectively (Table 3). Reduction in phytic acid was further slightly increased on soaking kidney beans in 4% acetic acid solution containing 2.5% sodium chloride. Formation of soluble sodium salt of phytic acid might be the reason for greater extraction of phytic acid from kidney beans in the presence of acid. However, the exact mechanism of leaching of phytic acid is still unknown. Reduction in phytic acid levels of various legumes during soaking in mineral acid solution has also been reported by earlier workers (Han 1988; Zhou 1993). Statistical analysis of the data revealed that soaking temperature significantly ($P<0.05$) affected the rate of extraction of phytic acid from kidney beans.

Effect of cooking on phytic acid. Phytic acid contents of soaked red kidney beans was further significantly ($P<0.05$) reduced on cooking by different ways (Table 4). Cooking in a pressure cooker caused maximum reduction in phytic acid content of the red kidney beans. Ordinary and microwave cooking also showed pronounced effect on reduction of phytic acid. Reduction in phytic acid was almost the same when kidney beans soaked in tap water or sodium chloride solution were cooked by either method. All these cooking processes reduced maximum amount of phytic acid from the kidney beans soaked in acetic acid solution with or without sodium chloride. It seems that soaking in acidic solution might have destructed inter and intra cellular membranes of the beans which facilitated leaching out of the antinutrient from the material during cooking. Ordinary and microwave cook-

Table 2

Effect of soaking on physical characteristics of raw red kidney beans

Soaking solution	Hydration capacity mg/seed	Hydration index	Swelling capacity (ml)	Cooking time (min)		
				Ordinary cooking	Pressure cooking	Microwave cooking
Unsoaked Kidney Beans	-	-	-	45	20	20
Simple Water 100°C-4 h	9.72 ± 1.7	62.30 ± 1.3	79.9 ± 1.2	33	15	15
Sodium Chloride Solution 100 °C-4 h	10.12 ± 1.5	58.80 ± 1.3	72.2±1.1	33	15	15
Acetic Acid Solution 100°C- h	9.30 ± 1.1	54.30 ± 1.4	70.2 ± 1.3	20	5	5
Acetic Acid + Sodium Chloride 100°C-4 h	9.00 ± 1.3	51.00 ± 1.1	68.0 ± 1.4	20	5	5

Mean ± SD Triplicate Sample.

Table 3

Effect of different soaking methods on phytic acid contents* of red kidney beans

Soaking condition		Simple water		Sodium chloride		Acetic acid		Acetic acid and Sodium chloride	
Temp. °C	Time (h)	Phytic acid g Kg^{-1}	% Removal	Phytic acid g Kg^{-1}	% Removal	Phytic acid g Kg^{-1}	% Removal	Phytic acid g Kg^{-1}	% Removal
30	1	10.79 (±0.84)	0.46	10.60 (±0.55)	2.21	9.81 (±0.60)	9.50	9.62 (±0.55)	11.25
	2	10.50 (±0.66)	3.13	10.36 (±0.67)	4.42	9.70 (±0.57)	10.51	9.22 (±0.62)	16.97
	4	10.09 (±0.69)	6.91	9.81 (±0.70)	9.50	9.22 (±0.49)	14.94	8.88 (±0.60)	18.08
100	1	10.00 (±0.81)	7.74	9.70 (±0.55)	10.51	8.71 (±0.56)	19.64	8.50 (±0.60)	21.58
	2	9.24 (±0.75)	14.76	9.00 (±0.51)	16.97	8.25 (±0.60)	23.89	7.93 (±0.55)	26.84
	4	9.16 (±0.67)	15.49	8.88 (±0.61)	18.08	8.08 (±0.52)	25.46	7.63 (±0.50)	29.61

Mean ± SD Triplicate Sample

Table 4
Effect of different cooking methods on phytic acid contents* of red kidney beans

Soaking solution	Ordinary cooking		Pressure cooking		Microwave cooking	
	Phytic acid g Kg^{-1}	% Removal	Phytic acid g Kg^{-1}	% Removal	Phytic acid g Kg^{-1}	% Removal
Unsoaked	8.05 (±0.26)	25.73	7.60 (±0.30)	29.74	8.00 (±0.20)	26.19
Simple water	6.80 (±0.20)	37.26	5.84 (±0.20)	46.12	6.20 (±0.18)	42.80
Sodium chloride solution	6.60 (±0.61)	40.95	5.65 (±0.50)	47.87	5.80 (±0.27)	46.49
Acetic acid solution	4.60 (±0.35)	57.56	3.88 (±0.60)	64.20	4.00 (±0.30)	63.09
Acetic acid + sodium chloride	4.10 (±0.17)	62.17	3.14 (± 0.60)	71.03	4.35 (±0.41)	59.87

Mean ± SD Triplicate Sample

Table 5
Effect of soaking and cooking on in vitro protein digestibility* of red kidney beans

Soaking solution	Soaking conditions	After soaking		After cooking	
		IVPD %	Improvement %	IVPD %	Improvement %
Raw (Unsoaked)	--	38.78 (±2.2)	--	53.80 (±3.0)	38.73 -
Simple water	100°C-4 h	40.23 (±2.5)	3.73	73.00 (±2.5)	88.24
Sodium chloride (2.5% W v^{-1})	100°C-4 h	40.0 (±3.0)	3.14	73.50 (±2.0)	89.53
Acetic acid (4% vv^{-1})	100°C-4 h	41.42 (±2.9)	6.80	74.50 (±2.7)	92.10
Acetic acid (4% v v^{-1})+ sodium chloride (2.5% W v^{-1})	100°C-4 h	41.33 (±1.8)	6.57	75.00 (±2.4)	93.39

* Mean ± SD, triplicate samples.

ing reduced phytic acid of the soaked beans by 37.26-62.17% and 42.80-59.87% respectively whereas 46.12-71.03% phytic acid was reduced on cooking kidney beans in a pressure cooker (Table 4). On the other hand, reduction in phytic acid was only 25.73-29.74% when unsoaked kidney beans were cooked by these three different cooking processes (Table 4). These results are consistent with the findings of other workers who reported that cooking of various food materials resulted significant reduction in phytic acid (Mameesh and Tomar 1993; Attia *et al* 1994).

Effect of soaking and cooking on protein digestibility. Table 5 shows the effect of soaking and cooking on *in vitro* protein digestibility (IVPD) of red kidney beans. IVPD of unsoaked kidney beans was 38.78% without cooking which became 40.23-41.42% as a result of soaking in tap water and other solutions at 100°C for 4 h. It is apparent from these results that protein degestibility was almost the same whereas significantly high amount of phytic acid (15.49-29.61%) was removed due to soaking (Table 3). Therefore, it can be concluded that improvement in protein digestibility by 3.41-6.80% could not be the result of removal of phytic acid from red kidney beans. However, it is possible that absorption of sufficient water from the soaking media might have decreased the hardness of the beans and facilitated proteolytic enzymes to attack easily on protein profile and as a result showed minor increase in its protein digestibility.

IVPD was significantly ($P<0.05$) improved as a result of cooking in a pressure cooker. On cooking, IVPD of unsoaked kidney beans was 53.80% while IVPD of soaked kidney beans increased from 73.0% to 75.0% after cooking (Table 5). It is apparent from these results that improvement in protein digestibility was almost the same (88.24-93.39%), whereas the amount of phytic acid extracted on cooking showed wide variations ranging from 46.12-71.03% (Table 4). These results again suggest that improvement in protein digestibility could not be related to the removal of phytic acid. These results confirm the findings of

Serraino *et al* (1985) who observed on improvement in protein digestibility due to removal of phytic acid from rape seed flour. Improvement in protein digestibility could be the result of some structural changes which might have occurred in protein profile and thus increased the accessibility of the proteins to enzymatic attack. Inactivation or removal of other antinutrients during cooking of kidney beans might be another reason for increasing the digestibility of protein as reported by earlier workers (Wu *et al* 1994).

Conclusion

It is concluded from these results that different soaking methods reduced the level of phytic acid from red kidney beans to various extents. Soaking red kidney beans in 4% acetic acid solution with or without 2.5 sodium chloride doubled the rate of extraction of phytic acid as compared with simple water soaking process. Significant reduction in cooking time was also noted after soaking in different solutions. Different cooking methods also brought about a greater reduction in phytic acid contents of red kidney beans. However, cooking in a pressure cooker caused maximum reduction in phytic acid contents of red kidney beans. It is also apparent from these findings that reduction in the level of phytic acid did not improve the digestibility of proteins. Removal of phytic acid may be attributed to leaching out of the antinutrient into the soaking solution under the influence of concentration gradient. Such losses may be taken as a function of changed permeability of seed coat. Soaking is an integral traditional method of processing leguminous grains in this part of the world and offers the dual advantage of reducing energy cost, by shortening cooking time as well as making the grains nutritionally superior.

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