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Domestic processing effects on some insoluble dietary fibre components of various food legumes

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Abstract

Effects of soaking and cooking methods were studied on neutral detergent fibre (NDF), acid detergent fibre (ADF), cellulose, hemicellulose and lignin contents of five food legumes. Black grams, chickpeas, lentils, and red and white kidney beans were soaked in tap water and sodium bicarbonate solution (1% w/v). Slight but significant increases in ADF (0.85–4.57%) and cellulose (3.44–6.59%) were observed on soaking food legumes in tap water. Soaking in sodium bicarbonate solution led to an appreciable increase of hemicellulose (44.4–58.9%) and cellulose (5.67–12.5%) but lignin contents remained unchanged. The dietary fibre components were variously reduced up on cooking the water-presoaked legumes by three different methods. However, pressure cooking showed a more pronounced effect on the reduction of these dietary fibre components than ordinary or microwave cooking methods. Pressure cooking caused reductions in NDF (28.5–35.3%), ADF (11.6–23.9%), cellulose (17.0–35.8%) and hemicellulose (37.6–42.4%) whereas increase in lignin content (15.2–27.8%) was observed. Reduction in hemicellulose was distinctly greater than that of cellulose content as a result of cooking the food legumes by these three cooking methods.

Keywords: Food legumes; Soaking; Cooking; Insoluble dietary fibre components

1. Introduction

The importance of dietary fibre in normal and therapeutic diets has been acknowledged by numerous authors in recent years (Brand, Snow, Nobhan, & Truswell, 1990; Schneeman, 1987). Dietary fibre consists mainly of soluble and insoluble fibre fractions which exert different physiological effects on human health. Soluble fibre lowers serum cholesterol and helps to reduce the risk of heart attack and colon cancer (Burkitt, Walker, & Painter, 1974; Kelsey, 1978; Trowell, 1972). However, cellulose, hemicellulose and lignin are the main components of insoluble dietary fibre which prevent or relieve constipation in humans due to absorption of water from the digestive track (Hill, 1974). Similarly, dietary fibre in human diets also reduces the risk of obesity, blood pressure, appendicitis, and many other diseases. Keeping in view the beneficial clinical effects of dietary fibre, it is important to collect data on both the dietary fibre and its profile in different foods.

Food legumes are considered an excellent source of dietary protein and are used as a substitute for expensive animal protein in human diets. Food legumes have also been used as part of the dietary treatment of diabetes (Jenkins et al., 1981; Thorne, Thompson, & Jenkins, 1983) and fortification of foods (Shehata, Darwish, El-Nahry, & Rarack, 1988). Food legumes are usually cooked by a boiling process before use. Pressure cookers and microwave ovens, however, can also be used for this purpose. Cooking brings about a number of changes in physical characteristics and chemical composition of food legumes. Cooking has also been shown to cause some structural changes in dietary fibre components of vegetables (Herranz, Vidal-Valverda, & Rojes-Hodelgo, 1981; Roehrig, 1990). However, very little information is available in the literature regarding the dietary fibre components of the cooked food legumes. Therefore, the present study was undertaken to investigate the effects of

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different soaking and cooking methods on the dietary fibre components of various food legumes.

2. Materials and methods

2.1. Materials

Chickpeas (*Circer arietinum*) black grams (*Vigna mungo*), lentils (*Lengs esculenta*), and red and white kidney beans (*Phaseolus vulgaris*) were obtained from the-Ayub Agricultural Research Institute, Resalewala, Faisalabad. These food legumes were cleaned, freed from broken seeds, dust and other foreign materials and then subjected to a soaking treatment prior to cooking.

2.2. Soaking treatment

A 50 g sample of each food legume was soaked in 250 ml of tap water and sodium bicarbonate solution (1% w/v) at 30 °C. After 4 h of soaking, the excess water was drained, the sample was rinsed twice with distilled water and then dried in a hot air oven (horizontal forced air drier, Proctor and Schwartz Inc., Philadelphia, PA) at 55 °C for 24 h. Presoaked food legumes (without drying) were cooked by three different cooking methods. Details of each cooking method are given below.

2.3. Ordinary cooking

Presoaked food legumes, were put in flat-bottom flasks fitted with an air condenser. Tap water (5 ml g^{-1}) was added and the samples were cooked on a hot plate for 60–120 min until the same degree of tenderness of each legume was achieved.

2.4. Pressure cooking

Presoaked food legumes were placed in one-litre beakers containing water (5 ml g^{-1}). The tops of the beakers were covered with aluminium foil and samples were cooked in a pressure cooker at 15 Ibs $in.^{-2}$ for 5–15 min until the same degree of tenderness of each legume was achieved.

2.5. Microwave cooking

Presoaked food legumes were placed in one-litre beakers containing Water (5 ml g^{-1}). The tops of the beakers were covered with aluminium foil and samples were cooked in a domestic microwave oven (Panasonic 115,550 cooking power) for 4–10 min until the same degree of tenderness of each legume was achieved.

After each cooking, excess of water was drained, the food legumes were then ground in a domestic electric grinder (Maulinex-France) and dried in hot air oven at 55 °C for 24 h before chemical analysis.

2.6. Chemical analysis

Neutral detergent fibre (NDF), acid detergent fibre (ADF), cellulose, hemicellulose and lignin contents in raw and cooked food legumes were estimated according to the methods described by Van Soest and Wine (1967) and McQueen and Nicholson (1979). In accordance with those researchers, a preliminary overnight incubation with bacterial alpha amylase was employed Triplicate determinations of all samples were performed for all parameters on a dry basis. Statistical analysis data of raw and cooked food legumes were recorded and standard deviations (SD) were calculated according to the method of Steel and Torrie (1980). Duncan's multiple range test was used to determine significant difference.

3. Results and discussion

Table 1 shows the percentage of each dietary fibre component in black grams, chickpeas, lentils, red and white kidney beans on a dry basis. These raw food legumes contained 23.4–29.8% NDF and 7.43–11.7% ADF whereas the cellulose, hemicellulose and lignin contents were 6.22–9.70%, 12.0–20.3% and 1.08–1.70%, respectively. These values showed variations from the reported values in the literature. In fact, soil, climate, collection time and botanical variety difference are factors which might be responsible for the variations observed.

Tables 2 and 3 show that soaking of food legumes in tap water and sodium bicarbonate solution caused some

Table 1
Dietary fibre components in various raw food legumes

Food legumes	Percentage				
	NDF	ADF	Cellulose	Hemicellulose	Lignin
Black grains	23.4 ± 1.01	11.7 ± 0.55	9.70 ± 0.53	12.0 ± 0.42	1.70 ± 0.11
Chickpeaks	25.5 ± 1.20	9.53 ± 0.49	8.45 ± 0.50	16.0 ± 0.39	1.08 ± 0.09
Lentils	29.8 ± 0.96	9.52 ± 0.51	8.10 ± 0.50	20.3 ± 0.52	1.42 ± 0.08
Red kidney beans	27.6 ± 0.97	7.43 ± 0.66	6.22 ± 0.44	20.2 ± 0.53	1.21 ± 0.12
White kidney beans	24.3 ± 1.00	9.32 ± 0.60	8.00 ± 0.41	14.9 ± 0.32	1.32 ± 0.10

NDF, neutral detergent fibre; ADF, acid detergent fibre; mean values ± SD (dry basis).

Table 2
Effect of soaking on neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents of various food legumes

Food legumes	NDF %			ADF %		
	Raw	Tap water	Sodium bicarbonate solution (1% w/v)	Raw	Tap water	Sodium bicarbonate solution (1% w/v)
Black grams	23.4 ± 1.01^a	23.8 ± 0.92^a	31.1 ± 1.30^b	11.7 ± 0.55^a	11.8 ± 0.88^a	10.3 ± 0.36^b
Chickpeas	25.5 ± 1.10^a	25.8 ± 0.77^a	33.4 ± 1.20^b	9.93 ± 0.49^a	9.70 ± 0.70^a	10.32 ± 1.22^b
Lentils	29.8 ± 0.96^a	30.1 ± 0.83^a	40.90 ± 1.30^b	9.52 ± 0.51^a	9.90 ± 0.55^a	8.15 ± 0.41^b
Red kidney beans	27.6 ± 1.41^a	27.9 ± 1.30^a	39.8 ± 1.11^b	7.43 ± 0.44^a	7.77 ± 0.36^a	8.15 ± 0.30^b
White kidney beans	24.3 ± 0.97^a	24.6 ± 0.88^a	31.4 ± 0.72^b	9.32 ± 0.60^a	9.58 ± 0.52^a	9.83 ± 0.41^b

Mean values ± SD (on dry basis).
Mean values in a row with different superscripts are significantly different at $p < 0.05$.

Table 3
Effect of soaking on cellulose, hemicellulose and lignin contents of various food legumes

Food legumes	Cellulose %			Hemicellulose %			Lignin %		
	Raw	Tap water	Sodium bicarbonate solution (1% w/v)	Raw	Tap water	Sodium bicarbonate solution (1% w/v).	Raw	Tap water	Sodium bicarbonate solution (1% w/v)
Black grams	9.70 ± 0.50^a	10.1 ± 0.41^a	10.3 ± 0.36^a	12.0 ± 0.42^a	12.00 ± 0.44^a	19.0 ± 0.40^b	1.70 ± 0.20^a	1.69 ± 0.20^a	1.67 ± 10.15^a
Check peas	8.45 ± 0.50^a	8.74 ± 0.45^a	9.00 ± 0.36^b	16.0 ± 0.39^a	16.1 ± 1.0^a	23.1 ± 0.91^b	1.08 ± 0.19^a	1.08 ± 0.17^a	1.00 ± 0.15^a
Lentils	8.10 ± 0.30^a	8.50 ± 0.42^b	7.00 ± 0.33^c	20.3 ± 0.52^a	20.3 ± 0.28^a	31.6 ± 0.25^b	1.42 ± 0.22^a	1.40 ± 0.15^a	1.15 ± 0.11^b
Red kidney beans	6.22 ± 0.21^a	6.63 ± 0.18^b	7.00 ± 0.18^c	20.2 ± 0.45^a	20.2 ± 0.36^a	31.6 ± 0.33^b	1.21 ± 0.10^b	1.14 ± 0.10^a	1.15 ± 0.12^b
White kidney beans	8.00 ± 0.41^a	8.29 ± 0.35^a	8.53 ± 0.30^b	14.9 ± 0.32^a	15.00 ± 0.21^a	$22.1+0.26^b$	1.32 ± 0.13^a	1.29 ± 0.15^a	1.30 ± 0.18^a

Mean values ± SD (on dry basis).
Mean values in a row with different superscripts are significantly different at $p < 0.05$.

changes in dietary fibre components. However, these changes were more pronounced on soaking food legumes in an alkaline solution of sodium bicarbonate. Soaking of these food legumes in tap water did not significantly alter NDF, hemicellulose or lignin contents on a dry matter basis. It is apparent from Table 2 that increase in ADF and cellulose contents was only from 0.85% to 4.57% and 3.44% to 6.59% as a result of soaking these food legumes in tap water. Soaking in sodium bicarbonate solution caused a sharp increase in hemicellulose (44.4–58.9%) and decrease in lignin contents (1.51–7.40%) in these five food legumes. However, increase in cellulose (5.67–12.6%) contents was also observed, except for lentils, on soaking these food legumes in alkaline solution. As a result of increase in hemicellulose and cellulose, NDF and ADF contents of these food legumes also increased by 29.2–37.4% and 3.58–9.69%, respectively, after alkali soaking (Table 2). Earlier workers also reported, significant increase in hemicellulose during soaking of lentils in sodium

Table 4
Effect of different cooking methods on neutral detergent fibre (NDF) and acid detergent fibre (ADF) of various food legumes

Food legumes	NDF %				ADF %			
	Raw	Ordinary cooking	Pressure cooking	Microwave cooking	Raw	Ordinary cooking	Pressure cooking	Microwave cooking
Black grams	23.4 ± 1.39^a	18.3 ± 1.11^b	15.7 ± 1.25^c	18.5 ± 1.09^b	11.40 ± 0.99^a	9.05 ± 1.32^b	8.82 ± 1.06^c	9.35 ± 1.20^b
Chickpeas	25.5 ± 1.37^a	20.1 ± 1.60^b	16.5 ± 1.09^c	20.1 ± 1.22^b	9.53 ± 1.00^a	7.88 ± 1.00^b	7.25 ± 0.73^c	8.05 ± 0.81^c
Lentils	29.7 ± 1.09^a	22.0 ± 0.73^b	20.9 ± 1.70^b	22.5 ± 1.32^b	9.52 ± 0.88^a	8.46 ± 0.73^b	8.29 ± 0.66^c	8.44 ± 0.49^b
Red kidney beans	27.8 ± 0.53^a	20.1 ± 0.74^b	18.0 ± 1.06^c	21.33 ± 1.01^b	7.43 ± 0.36^a	6.28 ± 0.30^b	5.86 ± 0.27^c	6.27 ± 0.60^b
White kidney beans	24.33 ± 1.11^a	17.9 ± 0.63^b	17.3 ± 0.73^c	19.14 ± 1.00^b	9.32 ± 0.79^a	8.50 ± 0.84^b	8.24 ± 0.66^c	8.350 ± 0.59^b

Mean values ± SD (on dry basis).
Mean values in a row with different superscripts are significantly different at $p < 0.05$.

Table 5
Effect of different cooking methods on cellulose, hemicellulose and lignin contents of various food legumes

Food legumes	Cellulose %				Hemicellulose %				Lignin %			
	Raw	Ordinary cooking	Pressure cooking	Microwave cooking	Raw	Ordinary cooking	Pressure cooking	Microwave cooking	Raw	Ordinary cooking	Pressure cooking	Microwave cooking
Black grams	9.70 ± 0.95^{a}	7.65 ± 0.41^{b}	7.75 ± 0.38^{b}	7.55 ± 0.42^{b}	12.0 ± 1.11^{a}	9.24 ± 0.62^{b}	6.89 ± 0.70^{c}	9.10 ± 0.88^{b}	1.70 ± 0.11^{a}	1.90 ± 0.08^{b}	2.07 ± 0.12^{c}	1.80 ± 0.13^{b}
Chickpeas	8.45 ± 1.21^{a}	6.70 ± 0.48^{b}	6.00 ± 0.45^{c}	6.90 ± 0.44^{b}	16.00 ± 1.08^{a}	12.2 ± 0.73^{b}	9.23 ± 0.48^{c}	12.1 ± 0.75^{b}	1.08 ± 0.16^{a}	1.18 ± 0.12^{a}	1.25 ± 0.11^{c}	1.15 ± 0.16^{a}
Lentils	8.10 ± 1.08^{a}	6.80 ± 0.72^{b}	6.60 ± 0.49^{c}	6.75 ± 0.33^{b}	20.3 ± 1.32^{a}	13.5 ± 0.80^{b}	12.6 ± 0.81^{c}	14.0 ± 0.90^{b}	1.42 ± 0.15^{a}	1.58 ± 0.21^{b}	1.19 ± 0.13^{c}	1.19 ± 0.13^{c}
Red kidney beans	6.22 ± 0.48^{a}	4.98 ± 0.22^{b}	4.44 ± 0.21^{c}	4.88 ± 0.24^{b}	20.2 ± 1.17^{a}	13.78 ± 0.42^{b}	12.1 ± 0.55^{c}	15.1 ± 0.50^{b}	1.21 ± 0.11^{a}	1.30 ± 0.08^{b}	1.40 ± 0.09^{c}	1.39 ± 0.11^{c}
White kidney beans	8.00 ± 0.59^{a}	7.00 ± 0.70^{b}	6.64 ± 0.53^{c}	6.85 ± 0.51^{b}	14.9 ± 1.00^{a}	9.41 ± 0.85^{b}	9.10 ± 0.73^{c}	10.79 ± 0.67^{b}	1.32 ± 0.14^{a}	1.50 ± 0.10^{b}	1.40 ± 0.11^{c}	1.50 ± 0.14^{b}

Mean values ± SD (on dry basis).
Mean values in a row with different superscripts are significantly different at $p < 0.05$.

bicarbonate solution at room temperature for 9 h (Vidal-Valvride, Frias, & Esteben, 1992).

The contents of NDF, ADF, cellulose hemicellulose and lignin were significantly ($p < 0.05$) reduced on cooking the presoaked food legumes (Tables 4 and 5). The ordinary cooking reduced NDF by 21.7–27.3% in these food legumes whereas pressure cooking and microwave cooking caused reduction in NDF contents of 28.5–35.3% and 21.0–24.5%, respectively. Similarly, ADF contents were reduced by 8.79–20.6% when food legumes were cooked by the ordinary method. However, pressure cooking and microwave cooking reduced ADF contents in these food legumes by 11.6–23.9% and 10.4–18.0%, respectively (Table 4). Table 4 shows that reduction in NDF and ADF contents was markedly greater by pressure cooking than by other cooking methods. It is also apparent from these results that reduction in NDF contents was comparatively greater than ADF contents as a result of cooking. Reduction in NDF and ADF contents in food legumes could be attributed due to partial degradation of cellulose and hemicellulose into simple carbohydrates during each cooking method as has already been observed by earlier workers (Rehman & Shah, 1994; Vidal-Valvride et al., 1992).

The cellulose, hemicellulose and lignin contents were significantly ($p < 0.05$) reduced (to various extents) when food legumes were cooked by three different methods (Table 5). However, pressure cooking showed a pronounced effect on reduction of these dietary fibre components compared to the other two cooking methods. As a result of pressure cooking, 17.0–35.8% of cellulose and 37.6–42.34% of hemicellulose contents were reduced in these five food legumes (Table 5). It is apparent from these findings that reduction in hemicellulose was comparatively greater than cellulose on cooking the food legumes. On the other hand, increase in the content of lignin was observed (to various extents) on cooking the food legumes as it has already been reported by earlier workers in lentils (Vidal-Valvride et al., 1992). However, pressure cooking caused maximum increases in lignin contents, by 15.7–21.8%. In general, the observed effect of cooking on individual dietary fibre components in the food legumes depended, not only on the type of food legume, but also on the cooking method involved Reductions in cellulose, and hemicellulose contents were reflected by the lower values of NDF and ADF of the cooked food legumes. Chemical degradation of cellulose into glucose, and hemicellulose into arabinose, xylose and galactose, might be reasons for the reduced contents of the dietary fibre components of the food legumes, up on cooking (Robinson & Lawler, 1986). The decrease in these dietary fibre components confirmed the findings of Vidal-Valvcide and Frias (1991) who observed that hemicellulose content in lentils was greatly reduced as a result of cooking. These results were also in good agreement with the findings of (Ellis, Dunning, & Flask, 1947) who reported the conversion of cellulose and hemicellulose into simple carbohydrates as a result of stream-pressure treatment. Similarly, many other workers also found marked decreases in cellulose and hemicellulose contents of various vegetables during cooking processes. (Anderson & Clydesdale, 1980; Herranz et al., 1981).

4. Conclusion

Black grams, chickpeas, lentils, red and white kidney beans were cooked for different time periods, depending on the type of legumes, in order to achieve a uniform degree of tenderness. It is apparent, from the result, that the dietary fibre components of these five food legumes were reduced to various extents as a result of cooking by the three different methods. Ordinary and microwave cooking reduced NDF by 21.7–27.3% and 21.0–24.5%, respectively, in these five food legumes. On the other hand 28.5–35.3% reduction in NDF content was observed upon cooking the food legumes in a pressure cooker. It is apparent from these results that the maximum amount of NDF was lost from the food legumes upon pressure cooking. Similar observations were also made in the case of other dietary fibre components of the food legumes. In order to minimize the losses of dietary fibre, it is suggested that legumes should be cooked, either by the ordinary method or in a microwave oven instead of a pressure cooker.

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