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Carbohydrate composition of wheat, wheat bran, sorghum and bajra with good chapati/roti (Indian flat bread) making quality

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Abstract

Varieties of wheat, sorghum and bajra having good chapati/roti making quality were studied for carbohydrate profile. Polysaccharide fractions (water-soluble, barium hydroxide-soluble, alkali-soluble and insoluble) were isolated from these cereals and wheat bran and their carbohydrate profiles were studied. Arabinoxylans were the major polysaccharides, other than starch and cellulose. The ratio of arabinose to xylose in whole-wheat flour and wheat bran was nearly 1.25:1 but the hemicellulose A in wheat flour was mainly xylan-type. Among the pentosans in barium hydroxide extract of sorghum, the hemicellulose A had more arabinose than xylose, but the hemicellulose B contained nearly equal amounts of arabinose and xylose. Bajra had arabinose and xylose in nearly equal amounts in both the barium hydroxide extract and alkali-soluble fractions. The alkali-insoluble residues were complexes of pentosans with cellulose and were strongly bound. Contents of dietary fibre varied between the cereals. Wheat bran had the highest among the four. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Carbhydrates; Arabinoxylans; Chapati; Roti; Cereals; Wheat; Sorghum; Bajra

1. Introduction

Wheat is one of the cereals used extensively in many parts of the world for the preparation of bread and many bakery products (Fincher & Stone, 1986; Hoseney, Wade & Finley, 1988). Chapati is a typical flat bread, and is common in many parts of India. Sorghum and bajra are less common cereals and roti, prepared from them, are favoured due to their characteristic texture and flavour (Hulse, Jiang & Pearson, 1980; Murthy & Kumar, 1995).

Arabinoxylans (pentosans) are known to play an important role in bread-making quality. These are proven to have significant influence on water balance and rheological properties of dough, and retrogradation of starch (Izydorczyk & Biliaderis, 1995; Vinkx & Delcour, 1996). The arabinoxylans are complex polysaccharides, having a xylan backbone with branches of arabinose residues in various linkages. The structures of these arabinoxylans vary significantly in different cereals and among varieties and have been topics of great academic interest (Aspinall, 1980).

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Cereals are usually consumed in large quantities and contribute considerable amounts of dietary fibre (DF). Dietary fibres are gaining interest due to their benefits against a variety of diseases such as diabetes, colon cancer (Plaami, 1997). Fermentation of dietary fibres to short chain fatty acids and their modulation of various physiological processes are of recent interest (Goni & Martin-Carron, 1998). The physiological functions of DF, and their chemical nature, vary from source to source. Wheat bran is a value-added source of DF.

The present paper deals with the carbohydrate composition of cereal varieties, i.e. wheat (Sonalika), sorghum (M354) and bajra (S203) having good chapati/roti (Indian flat bread) making quality.

2. Materials and methods

2.1. Materials

Sonalika variety of wheat (*Triticum aestivum*) was purchased from Agro-Seed Corporation, Agra, India. Wheat bran was obtained by processing wheat in a Buhler Automatic Lab Mill MLU 202. Sorghum (*Sorghum bicolor*, M354 variety) and bajra, also referred as

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pearl millet (*Pennisetum typhoideum*, S203 variety), were purchased from Agricultural College, Dharwad, India. They were milled to flours of 100% extraction in a hammer mill (Kamas-Slagg) using a 0.8-mm sieve.

Termamyl was procured from Novo, Denmark. Glucoamylase and dialysis bags (cellulose membranes, 12,000 cut off) were procured from Sigma Chemical Company, USA. All other reagents and chemicals used were of analytical reagent grade.

2.2. Methods

2.2.1. Extraction of polysaccharides

This was done essentially as described earlier (Salimath & Tharananthan, 1982; Swamy, Ramakrishnaiah, Kurien & Salimath, 1991). The flours (100 g) were treated with 70% ethyl alcohol (400 ml, room temperature (RT), ×3) to extract free sugars. The combined extracts were pooled and to the insoluble residue, water (500 ml) was added and cooked in boiling water bath for about 1 h to gelatinise starch. To the slurry, Termamyl (heat-stable amylase) was added (2 ml) and the mixture placed in a boiling water bath. Aliquots of 1–2 ml were taken and tested for the presence of starch by the I_2-KI test. Once the test showed negative, the slurry was cooled and digested with glucoamylase (Sigma, 200 mg) at 60°C for 4–5 h and tested for starch hydrolysis by the I_2-KI test. The digest was cooled, centrifuged and the supernatant containing water-soluble polysaccharides was dialysed against running tap water overnight with a few drops of toluene and then for 24 h against single-distilled water. The dialysate was lyophilised to get water-soluble polysaccharide. To the water-insoluble residue, saturated barium hydroxide solution (400 ml), containing sodium borohydride (260 mM), was added and extracted at RT for 16 h with stirring (×2; Gruppen, Hamer & Voragen, 1991). It was then centrifuged and the supernatant dialysed against sodium acetate buffer (0.2 M, pH 5.0) and distilled water. Barium hydroxide-insoluble residue was washed to neutral pH, dried and then taken for extraction with sodium hydroxide. The barium hydroxide-insoluble residue was mixed with 100 ml water, allowed to swell and 40% sodium hydroxide was added to make 10% concentration, under nitrogen atmosphere (Whistler & Feather, 1965). The extraction was done for 6 h. The suspension was centrifuged; the supernatant was kept in an ice bath and 50% acetic acid was added to precipitate hemicellulose A. The precipitate was centrifuged, washed with water (×3) and dried by solvent exchange (ethyl alcohol/ether). The supernatant remaining after precipitation of Hem A with 50% acetic acid was dialysed extensively (24 h) against running tap water and then distilled water and lyophilised to get hemicellulose B. The residue obtained with alkaline extraction was washed extensively with water until neutral to pH and dried by solvent exchange as above, to get the alkali-insoluble residue.

2.2.2. Analytical methods

Estimation of total carbohydrates was done by the phenol-sulphuric acid method (Mckelvy & Lee, 1969) and uronic acids by the carbazole method (Dische, 1947). Starch content in the flour was estimated after hydrolysing the flour with Termamyl and glucoamylase, and glucose was estimated by the glucose-oxidase method (Dahlquist, 1964). Protein content was determined in the flour by the Kjeldhal method. Sugar composition in the flour and water-insoluble fractions was examined after hydrolysing with 72% sulphuric acid at ice-cold temperature, followed by dilution to 10% of sulphuric acid and the boiling water bath temperature for 6–8 h. The water-soluble fractions were hydrolysed, either with 2N sulphuric acid at boiling water bath temperature for 6–8 h with air cool condenser, or 2N trifluoroacetic acid in sealed tubes at 100°C for 5–6 h. Sulphuric acid hydrolysates were neutralised with barium carbonate and deionised with Amberlite IR 120 H^+ resin. The trifluoroacetic acid hydrolysates were washed with water and flash evaporated until neutral. The sugars were analysed by paper chomatography (PC) using *n*-butanol–pyridine–water 6:4:3 by descending paper chomatography and by gas liquid chomatography (GLC) as alditol acetates (Sawardekar, Slonekar & Jeanes, 1967) on an OV-225 column at column temperature of 200°C using a Shimadzu GLC. Dietary fibre was isolated by the enzymatic method of Asp, Johansson, Hallmer and Siljestrom (1983). The soluble and insoluble dietary fibres were hydrolysed by the 72% sulphuric acid solubilisation method, followed by dilution to 10% acid. Sugar composition was determined by PC and GLC.

3. Results and discussion

3.1. Carbohydrates of wheat

Wheat is the major cereal consumed all over the world and a considerable amount of work has been done on the carbohydrates of wheat (Fincher & Stone, 1986; Hoseney, Wade & Finley, 1988; Izdorczyk & Biliaderis, 1995). Sonalika is one of the popularly consumed Indian wheat varieties used for the preparation of chapati — Indian flat bread (Shurpalekar, Kumar, Venkateshwar Rao, Ranga Rao, Rahim & Vatsala, 1976). Carbohydrate profiles of whole-wheat flour and its fractions have been studied. The flour is rich in carbohydrates (84.5%, Table 1) and contains 10% proteins. The content of starch is 58%. Sugar analysis of the flour indicated glucose, mainly, with small amounts of arabinose and xylose and minor quantities of rhamnose/fucose and uronic acid. The ratio of arabinose to xylose in whole-wheat flour was 1.25. The water-soluble polysaccharides were isolated after destarchifying the flour. This fraction contained mainly glucose. This could arise from β-glucans, resistant starch and some unhydrolysed starch. Small amounts of arabinose and xylose ,with rhamnose/fucose and uronic acid, were also observed. Izydorczyk and Biliaderis (1993) have studied the chemical composition of Canadian wheat varieties. They showed an arabinose to xylose ratio ranging from ~1:2 to ~1:1 in fractions varying in fractionation profile. Barium hydroxide has been used selectively to extract arabinoxylans from cereals by many workers (Gruppen, Hamer & Voragen, 1991; Izydorczyk & Biliaderis, 1995). The water-insoluble residue was extracted with barium hydroxide (yield, 4.3%). The barium hydroxide extract was rich in carbohydrates and contained arabinose, xylose and glucose. Glucose was also present. Small amount of mannose and galactose were also observed. This polysaccharide could be a complex mixture of arabinoxylan-type polysaccharide and β-glucans. The contents of β-glucans in wheat have been reported to be 0.8% on a dry weight basis (Henry, 1987). The barium hydroxide-insoluble residue was further extracted with 10% sodium hydroxide solution and hemicellulose A (Hem A) was precipitated with 50% acetic acid. The Hem A contained xylose, predominantly, with small amounts arabinose and glucose. This fraction may contain xylan-type polysaccharides, mainly, with small amounts of arabinoxylan-type polysaccharides and β-glucan type polysaccharides. The hemicellulose B (Hem B) contained high amounts of arabinose and xylose, found to be in the ratio of 0.9:1. Small amounts of glucose were also present. The alkali-insoluble residue still contained 40% non-glucose sugars. This suggests strong association of arabinoxylans with cellulose. The arabinoxylans are known to be bound strongly to cellulosic polysaccharides and are bound with ferulic acid residues forming strong ester and ether linkages (Ford & Hartley, 1989; Hartley & Jones, 1976). These associations make extraction of polysaccharides difficult. The ratio of arabinose to xylose in different varieties of wheat has been shown to vary (Izydorczyk & Biliaderis, 1995) from 0.5 to 1.0 and our studies showed the ratio of arabinose to xylose to be around 1.0 in most of the polysaccharide extracts, but Hem A contained mainly xylan-type polysaccharides.

3.2. Carbohydrates of wheat bran

Wheat bran is the by-product of wheat milling industries and is valued as a rich source of dietary fibre. The pentosans present in wheat bran add quality to chapati making and also add nutritive value as a rich source of dietary fibre (Adams, 1955; Brillouet & Mercier, 1981). Wheat bran was rich in carbohydrates (80%; Table 2) and contained 16% proteins. The content of uronic acid was high (5%), compared to whole-wheat flour. The pentoses were the major components, followed by glucose. The ratio of arabinose to xylose was 1.37. High amounts of pentoses in association with uronic acid would indicate presence of glucuronoarabinoxylans in the bran (Brillouet & Mercier, 1981). The starch content was 10.5%. This could be from the associated endosperm with the bran. The water-soluble polysaccharide contained glucose, mainly, with small amounts of arabinose and xylose. This may be due to the presence of β-glucan-type polysaccharides, and resistant starch, along with unhydrolysed starch. The content of uronic acid was 6.5%. Barium hydroxide-extracted arabinoxylans contained, principally, arabinose and xylose in a 0.8:1 ratio. Glucose may arise from the resistant starch that may be formed during gelatinisation. The barium hydroxide-insoluble residue was extracted with 10% sodium hydroxide. Both hemicelluloses, A and B, are rich in pentosans and contain small amounts of glucose (~17%; Adams, 1955). Small amounts of uronic acid

Table 1
Carbohydrate composition (%) of whole wheat flour and its isolated fractions[a]

	Yield	Total sugar	Uronic acid	Sugars identified						
				Rha/Fuc	Ara	Xyl	Man	Gal	Glc	Ara/Xyl ratio
Flour	(100)	84.5	2.6	2.0	10.0	8.0	–	–	80.0	1.25
WSP	10.0	88.0	2.6	1.4	1.2	4.3	–	–	93.1	0.28
BE	4.3	87.7	2.2	–	31.6	35.5	1.4	0.8	30.7	0.89
Hem A	2.2	94.8	3.7	–	16.3	71.3	–	–	12.4	0.23
Hem B	1.5	95.7	3.1	–	41.2	44.6	–	0.8	13.4	0.92
AIR	3.9	93.7	1.8	–	21.9	15.6	1.9	0.6	60.0	1.41

[a] WSP, water-soluble polysaccharides; BE, barium hydroxide extract; Hem A, hemicellulose A; Hem B, hemicellulose B; AIR, alkali-insoluble residue; Rha, rhamnose; Fuc, fucose; Ara, arabinose; Xyl, xylose; Man, mannose; Gal, galactose; Glc, glucose.

Table 2
Carbohydrate composition (%) of wheat bran and its isolated fractions[a]

	Yield	Total sugar	Uronic acid	Sugars identified						
				Rha/Fuc	Ara	Xyl	Man	Gal	Glc	Ara/Xyl ratio
Flour	(100)	80.7	5.0	–	37.0	27.0	–	–	26.0	1.37
WSP	2.4	88.0	6.5	1.3	11.1	8.4	–	–	79.2	1.32
BE	3.0	99.5	2.6	–	35.2	43.7	–	–	21.1	0.81
Hem A	9.0	94.0	2.3	–	38.4	43.2	–	1.9	16.5	0.89
Hem B	17.0	91.0	1.2	–	38.3	43.0	–	1.7	17.0	0.89
AIR	24.0	97.0	1.6	–	14.5	11.6	–	0.5	73.4	1.25

[a] WSP, water-soluble polysaccharides; BE, Barium hydroxide extract; Hem A, hemicellulose A; Hem B, hemicellulose B; AIR, alkali-insoluble residue; Rha, rhamnose; Fuc, fucose; Ara, arabinose; Xyl, xylose; Man, mannose; Gal, galactose; Glc, glucose.

were also present. Arabinose and xylose were in nearly equal amounts. Differences in the solubility of hemiceluloses A and B could be due to variation in their structures and also possible linkages with ferulic acid, uronic acid and other associated polysaccharides (Aspinall, 1980; Gruppen et al., 1991; Swamy et al., 1991). The alkali-insoluble residue still contained considerable amounts of pentoses, indicating association with cellulose. The content of arabinose was higher than xylose. It is interesting to note the strong association of pentosans with cellulose. Shiba, Yamada, Hara, Okada and Nagao (1993) reported extraction of water-soluble polysaccharides containing arabinose and xylose in nearly 1:1 ratio and containing short-chains of arabinose residues.

3.3. Carbohydrates of sorghum

Sorghum is one of the staple cereals in India, Pakistan, Central and Northern China and Australia. In parts of India, sorghum is made into a flat bread — roti which is different but still close to chapati and the textural properties are favoured by consumers. The roti prepared from sorghum resembles that made from bajra. Sorghum, variety M354, which has good roti-making quality (Chandrashekar & Desikachar, 1984) had a carbohydrate content of 88.4% (Table 3) and the content of proteins was 10%. The starch content was 73%. Glucose was the main sugar and could arise mainly from starch, cellulose and β-glucan types of polysaccharides (Woolard, Rathbone & Novellie, 1976, 1977). The water-soluble polysaccharide was rich in glucose. It contained small amounts of arabinose and xylose. Water-soluble extracts are known to contain high amounts of β-glucans with associated pentosans. This would also include resistant starch formed during the extraction. The barium hydroxide extract contained high amount of arabinose, followed by xylose and glucose. The ratio of arabinose to xylose was nearly 2.5:1. This may be due to the presence of a mixture of arabinan-type polysaccharides with arabinoxylan-types of polysaccharides or due to large numbers of arabinose residues attached to the branch points. The hemicellulose A contained higher amounts of arabinose than xylose, while hemicellulose B contained nearly equal amounts of arabinose and xylose. Associated glucose in these fractions could be due to resistant starch formed and β-glucans bound to the pentosans (Ramesh & Tharanathan, 1998; Woolard et al., 1976, 1977). It was shown by other workers that the ratio of arabinose to xylose varied in different parts of sorghum grain (Kavitha & Chandrashekar, 1992). The endosperm had about 10% pentoses, while the pericarp contained around 50% pentoses (Saldivar & Rooney, 1995). However, the ratio of arabinose to xylose was 2:1, both in endosperm and pericarp. The ratio of arabinose to xylose was 1.5:1 in the water extract of sorghum. These variations in the ratio of arabinose and xylose in different cereals lead to variations in types of arabinoxylans and hence their chemical and structural make up (Verbruggen, Beldman & Voragen, 1998; Verbruggen et al., 1998).

3.4. Carbohydrates of bajra

The roti prepared from bajra (pearl millet) has a typical texture, which is favoured by consumers. Bajra, variety S203, having good *roti*-making quality was selected for the study (Austin, Hanslas, Singh & Ram, 1971). These rotis when dry, have better keeping and textural qualities. The carbohydrate fractions are the major components of the cereals and contain small amounts of uronic acid. Conspicuously, the content of uronic acid in all fractions of bajra was small. The content of starch and proteins are 80 and 12%, respectively. Sugar composition of bajra flour revealed glucose, mainly, with small amounts of arabinose and xylose, along with galactose and mannose (Table 4). Galactose content is higher in bajra fractions than sorghum and

Table 3
Carbohydrate composition (%) of sorghum and its isolated fractions[a]

	Yield	Total sugar	Uronic acid	Sugars identified					
				Ara	Xyl	Man	Gal	Glc	Ara/Xyl ratio
Flour	(100)	88.4	2.6	4.1	3.1	–	1.1	91.7	1.33
WSP	1.7	98.0	+	0.3	2.1	1.3	0.5	95.8	0.14
BE	0.6	92.0	2.5	63.4	26.3	–	–	10.3	2.41
Hem A	0.1	80.0	3.4	64.2	23.1	–	–	12.7	2.77
Hem B	2.2	79.4	2.6	35.4	32.3	–	3.0	29.3	1.09
AIR	5.1	78.0	1.3	8.5	12.3	5.0	3.0	71.2	0.69

[a] WSP, water-soluble polysaccharides; BE, barium hydroxide extract; Hem A, hemicellulose A; Hem B, hemicellulose B; AIR, Alkali-insoluble residue; Rha, rhamnose; Fuc, fucose; Ara, arabinose; Xyl, xylose; Man, mannose; Gal, galactose; Glc, glucose. + Present, but could not be quantitated.

Table 4
Carbohydrate composition (%) of bajra and its isolated fractions[a]

	Yield	Total sugar	Uronic acid	Sugars identified					
				Ara	Xyl	Man	Gal	Glc	Ara/Xyl ratio
Flour	(100)	92.4	2.1	2.8	3.0	2.1	0.2	91.9	0.93
WSP	1.8	66.5	1.2	6.2	4.4	–	1.3	88.1	1.40
BE	9.5	86.2	1.7	45.5	36.6	–	2.4	15.5	1.24
Hem A	0.1	80.0	3.1	23.9	31.5	1.7	5.9	37.0	0.76
Hem B	1.7	85.4	2.1	44.4	41.7	0.6	4.1	9.2	1.06
AIR	4.1	84.7	1.1	16.6	10.0	1.9	4.5	67.0	1.66

[a] WSP, water-soluble polysaccharides; BE, barium hydroxide extract; Hem A, hemicellulose A; Hem B, hemicellulose B; AIR, alkali-insoluble residue; Rha, rhamnose; Fuc, fucose; Ara, arabinose; Xyl, xylose; Man, mannose; Gal, galactose; Glc, glucose. + Present, but could not be quantitated.

wheat. The galactose may arise from arabinogalactan-type polysaccharides. The water-soluble polysaccharides were isolated after hydrolysing starch with Termamyl and glucoamylase. The amount of uronic acid was 1.2%. Glucose was the major sugar, with small amount of arabinose and xylose in a 1.4:1 ratio. High glucose may be due to the presence of β-glucans, resistant starch formed during extraction and unhydrolysed starch molecules. The water-soluble polysaccharides were extracted at room temperature and at 50°C from pearl millet by earlier workers (Bailey & Sumrell, 1979) and the compositional studies indicated arabinose to xylose ratios of 1.5:1, 1.4:1, respectively. A ratio of arabinose to xylose in the water-soluble fraction of 1.1:3 and, in the water-insoluble residue, of 1.3:1, in pearl millet has been reported by Emiola and DeLa Rosa (1981). The water-insoluble residue was extracted with barium hydroxide in 9.5% yield. The fractions were rich in carbohydrates and contained arabinose and xylose, mainly, and were approximately in equal proportions. Small amounts of glucose are also associated with this fraction. The alkali-soluble polysaccharides were rich in carbohydrates. The Hem A has a higher amount of glucose than Hem B. The ratio of arabinose and xylose was about 0.76:1 in Hem A and 1:1 in Hem B. Pentosans are the major constituents of hemicellulosic fractions. Small amounts of galactose may arise from arabinogalactan-type polysaccharides. The ratio of arabinose to xylose in alkali-insoluble polysaccharide was 1.7:1. The alkali-insoluble residue contained considerable amounts of non-cellulosic polysaccharides. The complexes of cellulose with arabinoxylans appear to be quite strong in all three cereals/millets studied. This would also be due to the associated ferulic acid esters. High amounts of starch and low quantities of uronic acid and pentosans having arabinose and xylose in approximately 1:1 ratio are the characteristic features of bajra carbohydrates.

The cereals studied showed differences in the yield of various fractions and the amounts of constituent sugars. This reveals variations in polysaccharides present in the cereals. Pentosans are the major constituents of non-starch polysaccharides. Barium hydroxide-soluble polysaccharides, Hem A and Hem B, were rich in pentosans. The Ara/Xyl ratio of pentosans from these fractions showed marked variations among the cereals studied. Arabinoxylans of barium hydroxide-extracted polysaccharides might be highly branched in sorghum and bajra as indicated by high Ara/Xyl ratio whereas those of whole-wheat flour and wheat bran were less. Bajra had an intermediate value; Hem A of whole-wheat flour was of xylan-type, as indicated by a low Ara/Xyl ratio, and that from sorghum contained mainly arabinose indicating it to be rich in arabinan-type polysaccharides and it may also show high amounts of branching with arabinose. Arabinoxylan from Hem B of whole-wheat flour and wheat bran seemed to have the same degree of branching, whereas, in sorghum and bajra flours, the branching was higher.

These studies clearly showed variations in the ratio of arabinose and xylose in different fractions and their extractability. The pentosans are differently associated with β-glucan and cellulosic polysaccharides. The ester-linkages of pentoses with ferulic acid are likely to be different and their association with uronic acid would also render their solubilities different. Further studies to purify the pentosans from these are in progress to characterise them chemically, with a view to gaining an insight into structure-function relationships of pentosans in wheat, sorghum and bajra for chapati/roti-making quality.

3.5. DFs from whole-wheat flour, wheat bran, sorghum and bajra

DFs are known to be beneficial against a variety of diseases, including colon cancer and diabetes (Goni & Martin-Carron, 1998; Plaami, 1997). Though the amount of fibres in cereals is small, consumption of large quantities of cereals contribute to significant amounts in the diet. Wheat, sorghum and bajra are the main cereals consumed in India, mainly in the form of chapati/roti. Analysis of DFs from whole-wheat flour and wheat bran of Sonalika variety, sorghum M354 and bajra S203 is reported in Table 5. The content of DF was highest in wheat bran. Pentosans were the major polysaccharides, followed by glucose, which may arise

Table 5
Composition of dietary fibre from wheat flour, wheat bran, sorghum and bajra flours[a]

	Yield (%) of defatted flour	Total sugar	Sugars identified					
			Rha/Fuc	Ara	Xyl	Man	Gal	Glc
Wheat flour								
IDF	10.0	96.0	–	42.9	39.4	2.3	1.6	13.8
SDF	1.0	82.0	–	41.0	31.7	–	9.9	17.4
Wheat bran								
IDF	35.8	98.0	–	30.8	43.6	–	–	25.6
SDF	4.0	86.0	–	57.7	24.4	0.5	0.6	16.8
Sorghum flour								
IDF	6.0	74.0	–	33.9	29.7	3.0	2.6	30.8
SDF	1.0	81.0	–	18.3	14.2	5.2	9.6	52.7
Bajra flour								
IDF	5.0	97.0	1.5	29.7	31.6	–	4.8	32.4
SDF	3.0	81.3	5.0	26.1	24.6	–	11.4	32.9

[a] IDF, insoluble dietary fibre; SDF, soluble dietary fibre; Rha; rhamnose; Fuc, fucose; Ara, arabinose; Xyl, Xylose; Man, mannose; Gal, galactose; Glc, glucose.

mainly from cellulose and β-glucans. The soluble dietary fibre contained small amounts of mannose and galactose. The whole-wheat flour contained around 11% DF. Arabinose and xylose were in higher amounts followed by glucose (Cho, DeVries & Prosky, 1997). Strong association of pentosans with cellulose and β-glucans could be the reason for variations in their solubility. The sorghum M354 variety contained around 6% insoluble dietary fibre and 1% soluble DF. Glucose was the major sugar, followed by arabinose and xylose. Small amounts of mannose and galactose were also present. Bajra S203 variety contained 5% insoluble dietary fibre and 3% soluble DF. Arabinose, xylose and glucose were in nearly equal amounts. Small amounts of deoxysugars and galactose were also present. The amounts of DF and their chemical nature bring about variations in the functionality of DF and their fermentation characteristics (Bourguin, Titgemeyers & Fahey, 1996).

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