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Food Chemistry 100 (2007) 1365–1370

Food Chemistry

www.elsevier.com/locate/foodchem

Influence of fibre from different cereals on the rheological characteristics of wheat flour dough and on biscuit quality

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Received 2 May 2005; received in revised form 5 December 2005; accepted 7 December 2005

Abstract

Demand for health oriented products such as sugar-free, low calorie and high fibre products is increasing. One such recent trend is to increase the fibre content in food products to overcome health problems such as hypertension, diabetes, and colon cancer, among others. Consumption of high fibre products consisting of indigestible cellulose, hemicellulose, lignin and gums have several health benefits. Apart from these benefits, β-glucan-rich fibres have the benefit of reducing the absorption of glucose. Fibre sources from wheat, rice, oat and barley were used to study their influence on rheological characteristics of wheat flour dough and biscuit making quality. Ash, total protein and dietary fibre content of bran samples ranged between 4% and 10%, 12% and 14% and 20.4% and 49.5%, respectively. Farinograph characteristics of the wheat flour-bran blends showed increase in water absorption from 60.3% to 76.3% with increase in the level of bran from 0% to 40%. The resistance to extension values as well as extensibility of the dough decreased with increase in the bran level. The spread ratio of the biscuits prepared from wheat, rice and oat bran blends decreased from 8.38 to 7.52, whereas the same increased to 9.3 for biscuits prepared from barley bran blends. The breaking strength values of biscuits ranged between 1.34 and 3.83 kg. Highly acceptable biscuits could be obtained by incorporating 30% of oat bran or 20% of barley bran in the formulation.

Keywords: Cereal fibre; Rheological characteristics; Dietary fibre and Biscuit

1. Introduction

Biscuits are the most popular bakery items consumed nearly by all levels of society. This is mainly due to its ready to eat nature, good nutritional quality, and availability in different varieties and affordable cost. Most of bakery products are used as a source for incorporation of different nutritionally rich ingredients for their diversification. Several health products have now become available. Dietary fibre plays a very important role in the human diet. Dietary fibre, consisting of indigestible cellulose, hemicellulose, lignin, gums and mucilage, provides a variety of health benefits. Soluble fibre is known for its hypocholesterolemic effect and insoluble fibre is known for reduction in the risk of colon cancer. β-Glucan is known for reduction in the risk of colon cancer and is known to reduce the absorption of glucose in the digestive system (Pomeranz, 1988; Potty, 1996). High fibre ingredients exhibit many properties that influence the physiological functions of foods. Several workers have used fibre sources such as wheat bran, oat bran, corn bran, barley bran and psyllium husk, among others to prepare high fibre bread (Laurikainen, Härkönen, Autio, & Poutanen, 1998; Pomeranz, Shogren, Finney, & Bechtel, 1977; Sidhu, Suad, & Al-Saqer, 1999; Wang, Rosell, & Barber, 2002). Studies have been carried out using coconut residue as a source of fibre in the preparation of cookies without affecting the organoleptic properties of the product (Khan, Hagenmaier, Rooney, & Mattil, 1976). Brewers' spent grain was used as a source of fibre for incorporation in cookie formulation (Prentice, Kissell, Lindsay, & Yamzaki, 1978). Leelavathi and Rao (1993) reported that raw wheat bran up to 30% could be used to substitute flour in the preparation of high fibre biscuits.

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doi:10.1016/j.foodchem.2005.12.013

Rice bran besides serving as a good source of vitamins is also a good source of dietary fibre (Babcock, 1987; Saunders, 1990; Skurray, Nguyen, & Wooldridge, 1988). Both full fat rice bran and defatted rice bran have been incorporated into many bakery products such as multigrain breads, doughnuts, pancakes, muffins and waffle mixes, among others (Saunders, Sloan, & James, 1988). Similarly, Knuckles, Hudson, Chiu, and Sayre (1997) reported that β-glucan enriched barley fraction increased water absorption in bread and pasta and breads prepared containing 20% barley fraction were highly acceptable. Studies were carried out to see the effect of both hypoglycemic and cholesterolemic effects of barley in bread making (Asna Urooj, Vinutha, Puttaraj, Leelavathi, & Rao, 1998). High fibre sugar – snap cookies were prepared using different cellulose of different particle size and carboxymethylcellulose or pectin coated cellulose (Gorczyca & Zabik, 1979).

The main objective of this research was to find the potential use of fibre sources from four cereals on the rheological properties of wheat flour dough and on the quality of biscuits.

2. Materials and methods

2.1. Materials

Commercial wheat flour having 11.2% moisture, 10.3% protein and 0.45% ash was used in the study. Cereal fibre sources, namely wheat bran, rice bran, oat bran and barley bran were used to enrich the fibre content in the biscuits. Wheat bran was collected from a commercial roller flour mill of 20 TPD (Buhler mill, Buhler AG, Uzwil, Switzerland), where the flour extraction rate was 71%. Defatted rice bran was collected from commercial rice mill of 2 TPH capacity (M/s G. G. Dandekar Machine Works Ltd, Biwandi, Thane District, Maharashtra, India). Commercially available oat bran procured from the local market was used (Bagrry's, Bagrry's India Ltd., X-2, Hauz Khas, New Delhi, India). Whole barley was procured from Dharwad Agricultural University, Dharwad. Barley was de-husked in a huller (No. 1, Ganesha Engineering Works, Chennai, India) and ground in disc mill (12 in. plate, Bemco Emery Stone Pvt. Ltd., Belgaum, India). The over-tailings of 213 μm mesh, rich in fibre, was used in the study.

2.2. Chemical analysis

Bran samples were powdered to pass through 150 μm sieve and were analysed for different parameters. Moisture, ash, protein and fat were determined according to the standard AACC (2000) methods. Nitrogen content was estimated by semi micro-Kjeldhal method and was converted to protein by using a factor of 6.25. Soluble, insoluble and total dietary fibre contents were estimated according to Asp, Johnson, Hallomer, and Siljestrom (1983). All analyses for samples were carried out in triplicate and expressed as the mean value and standard deviation was calculated.

2.3. Dough characteristics

Blends of 0%, 10%, 20%, 30% and 40% were prepared by substituting the flour with bran. The effect of different bran levels on dough rheology was determined by Farinograph (Model: E-380, Brabender OHG, Duisburg, Germany) according to the standard AACC (2000) methods. Parameters measured were water absorption, dough development time, dough stability and mixing tolerance index. The elastic properties of dough with different levels of bran were measured using extensograph (Brabender, Duisburg, Germany) according to the standard AACC (2000) methods. The parameters studied were resistance to extension (R), extensibility (E), ratio figure (R/E) and energy (Area).

2.4. Baking tests

Test baking of biscuits was carried out for blends containing different levels of fibre. The formula used was: 300 g flour, 90 g sugar, 60 g shortening (Marvo brand, M/s. Hindustan Lever Ltd., India), 3 g sodium chloride, 1.2 g sodium bicarbonate, 3 g ammonium bicarbonate, 6 g dextrose (Qualigens Glaxo India Ltd., Mumbai, India), 6 g skimmed milk powder (Sabarkantha District Co-opearative Milk Producer's Union Ltd., Himantnagar, India) and 54–56 ml water. Sugar and fat were creamed in a Hobart mixer (N-50) with a flat beater for 3 min at 61 rpm. Sodium bicarbonate, sodium chloride and ammonium bicarbonate were dissolved in water and added to the cream and mixed for 5–6 min at 125 rpm to obtain a homogeneous cream. Flour sieved with skimmed milk powder was added to the above cream and mixed for 3 min at 61 rpm. Biscuit dough was sheeted to a thickness of 3.5 mm, cut using a circular mould (51 mm dia), and baked at 205 °C for 9–10 min. After baking, biscuits were cooled to room temperature, packed in polypropylene pouches and sealed.

2.5. Evaluation of biscuits

2.5.1. Physical characteristics

Diameter (W) and thickness (T) of biscuits were measured by placing them edge-to-edge and stacking, respectively. Biscuits were rearranged and measurements were made. The spread ratio W/T was calculated. The objective evaluation of texture expressed as breaking strength (kg, force) was measured using the triple beam snap (three-point break) technique of Gains (1991) using an Instron Universal Testing Instrument (Model 4301, Instron Ltd., High Wycombe, Bucks, UK).

2.6. Colour measurement

Objective evaluation of surface colour for biscuit samples was measured using a UV–vis recording spectrophotometer (Model UV 2100, Shimadzu Corporation, Kyoto, Japan) with a reflectance attachment. The values were expressed in terms of colour difference (ΔE) and percent whiteness (W).

2.7. Sensory evaluation

Biscuit samples were presented in sealed pouches coded with different numbers to six panelists and were asked to rate each sensory attribute by assigning a score for surface colour, surface characteristics, texture, taste and mouthfeel.

2.8. Statistical analysis of data

The sensory analysis data was statistically analysed and the treatments were tested using Duncan's multiple range test (Steel & Torrie, 1980).

3. Results and discussion

3.1. Chemical characteristics of fibre samples

The mean values for analysis of all fibre samples are shown in Table 1. The moisture content of rice bran was 10.56% and that of other bran samples ranged between 4.92% and 7.68%. Ash content of rice bran was as high as 10% and that of all other bran samples ranged between 4% and 5.7%. The fat content was in the range of 4–8.0% and protein content was 12% and 14%. The dietary fibre for oat bran was 20.4% and it ranged between 40% and 47.5% for all other bran samples. The total dietary fibre content (TDF) of wheat bran is in agreement with results obtained by Pomeranz, Shogren, and Finney (1976). Soluble dietary fibre (SDF) content of wheat bran and rice bran was 5.01% and 4.33%, respectively, whereas that of oat and barley bran was 8.9% and 10.8%, respectively.

3.2. Influence of fibre on dough mixing properties

Incorporation of bran from different sources at 0%, 10%, 20%, 30% and 40% levels showed differences on the dough mixing properties as measured by Farinograph. The results are indicated in Fig. 1.

Addition of bran samples from different sources mainly increased the water absorption. By increasing the bran level

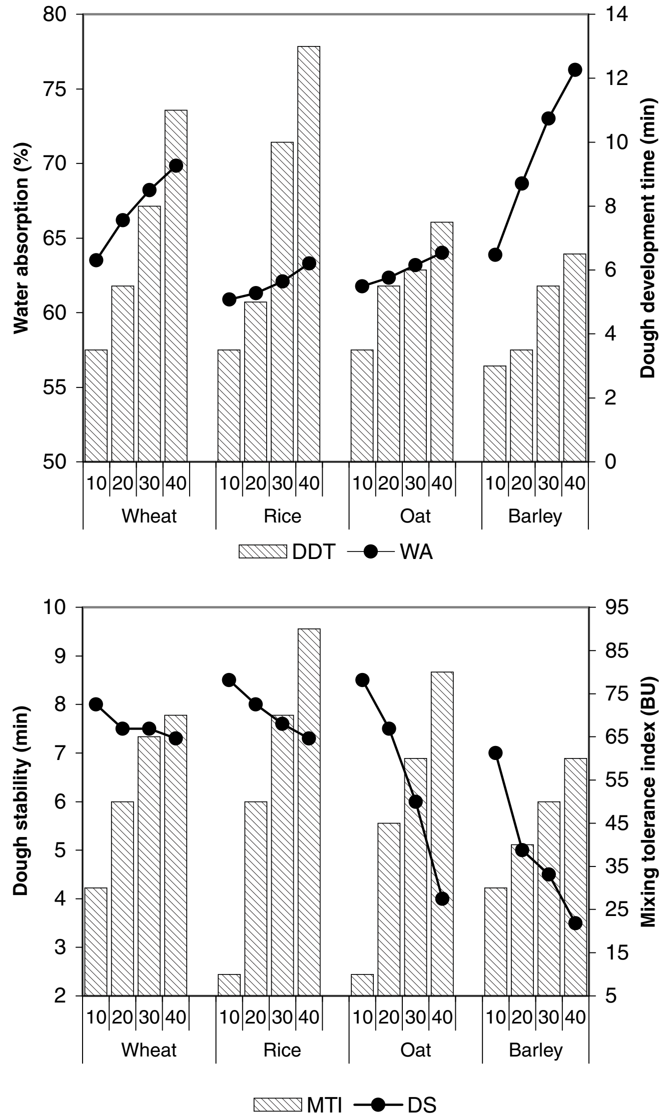

Fig. 1. Farinograph characteristics of wheat flour- bran blends; WA, water absorption (%); DDT, dough development time (min); MTI, mixing tolerance index (BU); and DS, dough stability (min) (control flour: WA, 60.54; DDT, 2.5; MTI, 10; DS, 9.5).

from 10% to 40% the highest increase in water absorption was found with the addition of barley bran (63.88–76.28%) and for wheat bran (63.52–69.85%). The increase in the water absorption in the case of oat bran blends and rice bran blends was marginal. Similar effects on water

Table 1
Chemical characteristics of fibre sources

Parameters	Wheat bran	Rice bran	Oat bran	Barley bran
Moisture (%)	7.68 ± 0.03	10.56 ± 0.02	6.45 ± 0.04	4.92 ± 0.03
Ash[a] (%)	5.70 ± 0.05	10.00 ± 0.06	4.00 ± 0.04	5.00 ± 0.04
Fat[a] (%)	4.00 ± 0.05	8.00 ± 0.08	5.00 ± 0.8	5.00 ± 0.04
Protein[a] (%)	13.12 ± 0.10	13.00 ± 0.15	12.0 ± 0.13	14.0 ± 0.18
Total dietary fibre[a] (%)	47.50 ± 0.36	40.00 ± 0.28	20.4 ± 0.19	45.0 ± 0.21
Soluble dietary fibre[a] (%)	5.01 ± 0.04	4.33 ± 0.05	8.9 ± 0.04	10.8 ± 0.04

Values are means ± standard deviations ($n = 3$).
[a] On 14% moisture basis.

absorption was observed by Barber, Barber, and Martinez (1981) and Pomeranz et al. (1977) when wheat bran or rice bran was added, respectively. Rosell, Rojas, and Benedito de Barber (2001) reported that the differences in water absorption is mainly caused by the greater number of hydroxyl group which exist in the fibre structure and allow more water interaction through hydrogen bonding. Extent of increase in dough development time (DDT) was high in the case of wheat and rice bran blends. Dough stability, which indicates the dough strength, decreased significantly from 8.5 to 4 and 7.0 to 3.5 min in the case of oat and barley blends, respectively, whereas the extent of decrease was relatively marginal in the case of wheat and rice bran blends. Greater effects were observed on the mixing tolerance index values (MTI). Similar results were reported by Laurikainen et al. (1998) for the addition of rye bran. The results showed weakening of the dough with the increasing level of bran.

3.3. Influence of fibre on the elastic properties of the dough

The effect of incorporation of different bran samples at varying levels on extensible properties is illustrated in Fig. 2. The resistance to extension values gradually decreased for blends with increasing levels of oat and barley bran blends, respectively, whereas it increased for blends with increasing level of wheat and rice bran. This may likely be due to the interaction between polysaccharides and proteins from wheat flour as reported earlier by Jones and Erlander (1967). The extensibility values were greatly reduced by the addition of bran from either of the sources. The ratio figure increased with the increasing level of bran indicating the dough becoming harder in the presence of bran. The extent of increase in barley bran blends was marginal indicating the dough becoming softer. The R/E ratio values increased to a greater extent in the case of rice bran

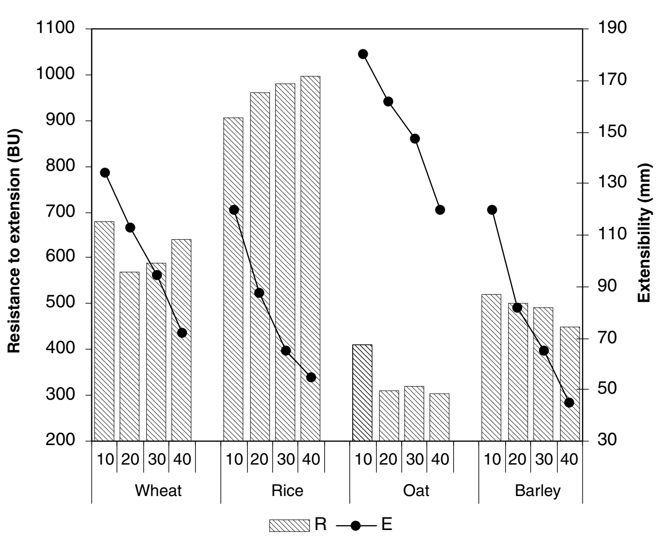

Fig. 2. Extensograph characteristics of wheat flour- bran blends; R, resistance to extension (BU); E, extensibility (mm) (control flour: R, 560; E, 180).

blends from 3.11 for the control to 18.09 for 40% incorporation. It gradually increased from 3.11 to 8.88 and 10.0 for wheat and barley bran blends, respectively. In the case of oat bran blends there was a marginal decrease in R/E values. Area under the curve decreased with the increase in the level of bran in the blends.

3.4. Influence of fibre on physical characteristics of biscuits

Biscuits prepared using 0%, 10%, 20%, 30% and 40% of different bran samples in the blends were evaluated for various physical and sensory characteristics. Incorporation of wheat bran decreased the spread of the biscuits from 55.3 to 52.8 mm without much change in the thickness of the biscuits (Table 2). Hence the spread ratio decreased from 8.38 to 7.73. Biscuits became harder as seen in the increase in breaking strength values from 1.34 to 2.11 kg. Incorporation of rice bran did not affect the thickness of the biscuit but reduced the spread of the biscuits from 55.3 to 51.2 mm. Biscuits became harder as seen in the increasing breaking strength values especially at 30% and 40% levels of rice bran and were as high as 2.38 and 3.8 kg, respectively. Oat bran incorporation showed an increase in spread (55.3–56.0 mm) and thickness (6.6–7.4 mm). Biscuits were crisp even at the level of 40% as seen in the breaking strength values, which increased very marginally. Barley bran incorporation reduced the spread values from 55.3 to 51.2 mm and thickness from 6.6 to 5.5 mm. Biscuits became harder with increase in the level of barley bran and 30% incorporation of barley had a breaking strength value of 2.15 kg.

Measurement of colour of the biscuits showed that the biscuits became darker with increasing level of either of the bran except for barley bran incorporation where the percent whiteness was reduced marginally.

3.5. Influence of fibre on sensory characteristics of biscuits

As seen in Table 3, colour of biscuits had low scores with increase in the level of bran. Rice bran incorporation increased the darkness and reduced the surface smoothness. Above 30% incorporation of rice bran in the formulation biscuits had dark crumb colour and very hard texture. Taste and mouthfeel of the biscuits was affected at 20% level. Biscuits had a dry mouthfeel at 20% level. Incorporation of wheat and oat bran showed similar sensory characteristics at all levels. On the other hand, barley bran incorporation reduced the surface smoothness at 30% level and beyond. The crumb colour darkened beyond 20%. At 10% incorporation, each bran samples did not affect the quality of biscuits. Quality of biscuits was acceptable at 20% for wheat bran and barley bran and 30% for oat bran only.

3.6. Dietary fibre composition of fibre rich biscuits

Dietary fibre was estimated for control biscuits (100% wheat flour) and biscuits containing wheat bran (20%), rice

Table 2
Influence of fibre on the physical parameters of biscuits

Sample	Diameter[a] (W, mm)	Thickness[a] (T, mm)	Spread ratio[a] (W/T)	Breaking strength[Ab] (g)	Whiteness[a] (%)	Colour difference[a] (ΔE)
Control	55.3b ± 0.29	6.60a ± 0.16	8.38c ± 0.21	1.34k ± 18.42	17.12b ± 0.09	46.84k ± 0.18
Wheat bran (%)						
10	55.0c ± 0.24	6.6a ± 0.11	8.30c ± 0.25	1.38j ± 20.25	16.67c ± 0.17	47.20j ± 0.14
20	54.2d ± 0.26	6.8a ± 0.12	7.91e ± 0.29	1.57j ± 18.96	13.41h ± 0.12	50.98f ± 0.16
30	53.4d ± 0.28	6.8a ± 0.16	7.52f ± 0.20	2.00e ± 20.29	13.33h ± 0.19	51.54e ± 0.12
40	52.8e ± 0.29	6.8a ± 0.19	7.73e ± 0.24	2.11d ± 21.20	11.25i ± 0.15	54.25c ± 0.14
Rice bran (%)						
10	54.6c ± 0.25	6.6a ± 0.11	8.02d ± 0.20	1.35k ± 15.29	14.52ef ± 0.19	49.90h ± 0.18
20	53.6d ± 0.29	6.6a ± 0.15	8.12d ± 0.22	1.96f ± 18.20	14.28fg ± 0.21	50.48g ± 0.20
30	52.8e ± 0.31	6.8a ± 0.15	7.76e ± 0.24	2.38c ± 20.24	11.44i ± 0.25	55.16b ± 0.25
40	51.2f ± 0.35	6.8a ± 0.19	7.52f ± 0.31	3.83a ± 32.21	10.12j ± 0.29	57.09a ± 0.29
Oat bran (%)						
10	54.8c ± 0.18	6.6a ± 0.08	7.60f ± 0.09	1.38j ± 12.25	20.26a ± 0.09	43.41l ± 0.05
20	54.8c ± 0.23	6.6a ± 0.13	8.30c ± 0.18	1.39j ± 15.56	14.16g ± 0.12	50.12gh ± 0.14
30	55.6b ± 0.26	6.8a ± 0.18	8.18d ± 0.21	1.47i ± 19.63	13.85g ± 0.19	50.34g ± 0.18
40	56.0a ± 0.29	6.8a ± 0.21	8.24c ± 0.28	1.49i ± 21.21	11.99i ± 0.22	53.04d ± 0.20
Barley bran (%)						
10	53.9d ± 0.14	6.0b ± 0.09	8.99b ± 0.05	1.58h ± 10.23	16.60c ± 0.08	47.40j ± 0.09
20	53.6d ± 0.19	6.0b ± 0.19	8.98b ± 0.16	1.88g ± 15.32	15.94d ± 0.12	47.92i ± 0.16
30	51.3f ± 0.21	5.4c ± 0.22	9.50a ± 0.21	2.15d ± 19.23	14.69e ± 0.15	50.03gh ± 0.18
40	51.2f ± 0.24	5.5c ± 0.28	9.34a ± 0.23	2.65b ± 21.05	14.39ef ± 0.24	51.72e ± 0.22
SEM[B] (±)	0.22	0.09	0.11	19.56	0.10	0.11

Values for a particular column followed by different letters differ significantly ($p < 0.05$).
Values are means ± standard deviations ([a] $n = 4$, [b] $n = 10$).
[A] Objective measurement.
[B] Standard error of mean at [a] 45 degrees of freedom, [b] 153 degrees of freedom.

Table 3
Influence of fibre on the sensory[A] quality of biscuits

Sample	Colour (10)	Surface character (10)	Crumb colour (10)	Texture (20)	Taste (20)	Mouthfeel (10)	Total score (80)
Control	8.41a	8.16a	8.33a	17.66a	17.33ab	8.25ab	68.14a
Wheat bran (%)							
10	8.16ab	8.00a	7.83abc	17.75a	17.75a	8.08ab	67.57ab
20	7.33abcd	7.58ab	7.33abcd	17.33abc	17.33ab	7.75abc	64.65ab
30	7.43abc	7.41ab	7.08bcd	16.41bcd	16.41ab	7.16bcd	61.89bc
40	6.33cd	6.75bcd	6.58cde	15.50def	15.5bcd	6.5ef	57.16d
Rice bran (%)							
10	7.58abc	8.16a	7.33abcd	16.50abcd	15.83bc	6.33def	61.73b
20	6.16cd	7.75ab	5.66eg	14.66efg	14.33d	5.50fg	54.06de
30	4.83ef	5.83d	4.66gh	14.16g	12.16f	4.33hi	45.97g
40	4.16g	4.16e	3.66h	11.66h	10.66g	3.33i	37.63h
Oat bran (%)							
10	7.83ab	8.00a	8.00ab	17.83a	17.00ab	8.00ab	66.56ab
20	7.16abcd	7.41ab	7.16abc	16.91abc	17.25ab	7.91abc	63.80ab
30	7.08abcd	7.16abc	6.91bcd	16.25bcd	16.41ab	7.33abcd	61.14c
40	6.00cde	6.33cd	6.08def	15.33ef	15.33cd	6.25ef	57.32d
Barley bran (%)							
10	8.17a	8.67a	7.83abc	17.67a	18.00a	8.5a	68.67a
20	7.33abcd	7.67ab	7.00bcd	16.00cd	16.67ab	6.83cde	61.50bc
30	6.67bcd	6.83bd	6.33def	14.33fg	14.67cde	5.83fg	54.66de
40	5.67e	6.00d	5.50g	12.67h	13.33ef	5.00gh	48.17f
SEM[B] (±)	0.46	0.32	0.37	0.39	0.46	0.35	1.81

[A] Values for a particular column followed by different letters differ significantly ($p < 0.05$).
[B] Standard error of mean at 85 degrees of freedom.

bran (10%), oat bran (30%) and barley bran (20%). As seen in Table 4 the total dietary fibre (TDF) content of biscuits containing bran from any of the sources was higher than the control. Incorporation of 20% barley bran increased the total dietary fibre content from 1.6% to 9.3% and incorporation of oat bran (30%) and wheat bran (20%) showed

Table 4
Dietary fibre composition of biscuits

Biscuit	SDF (%)	IDF (%)	TDF (%)
Control	1.2 ± 0.18	0.4 ± 0.08	1.6 ± 0.06
Wheat bran (20%)	2.0 ± 0.21	4.9 ± 0.18	6.9 ± 0.21
Rice bran (10%)	1.9 ± 0.28	1.6 ± 0.11	3.5 ± 0.19
Oat bran (30%)	2.8 ± 0.18	3.5 ± 0.12	6.3 ± 0.15
Barley bran (20%)	2.4 ± 0.21	6.9 ± 0.14	9.3 ± 0.19

SDF, soluble dietary fibre; IDF, insoluble dietary fibre; TDF, total dietary fibre, values are means ± standard deviations ($n = 3$).

an increase to 6.3% and 6.9%, respectively. The extent of increase in the TDF in rice bran biscuits was comparatively low although the addition of rice bran was 10%. These results are in agreement with those of found by Abdul Hamid and Siew Luan (2000), who prepared breads using defatted rice bran and sugar beet fibre. Soluble dietary fibre (SDF) for oat bran biscuits had a maximum value of 2.8% and it ranged between 2% and 2.4% for wheat bran and barley bran biscuits. Rice bran biscuits had a minimum of 1.9%. Insoluble dietary fibre (IDF) was at its maximum in biscuits containing barley bran at 6.9% and minimum of 1.6% for rice bran biscuits.

4. Conclusions

Addition of bran as a source of fibre from cereals (wheat, rice, oat and barley) to wheat flour effected the rheological characteristics in various ways. Biscuits containing wheat bran (20%), oat bran (30%) and barley bran (20%) were highly acceptable. The dietary fibre composition of these biscuits showed that fibres, which play a very important role, could be used for enriching the fibre content of biscuits. These studies have shown the potential of developing fibre-rich biscuits in order to increase the dietary fibre intake.

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