

Research Article

Functional properties and anti-nutritional factors in cereal bran

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Abstract

Various cereal brans (wheat, rice, barley and oat) were investigated for proximate composition, functional characteristics and certain anti-nutritional factors to assess their potentiality as protein and fibre sources. The major findings of this study are as follows: crude protein ranged from 9.6-15.03%, fat 4.07-19.31%, dietary fibre 14.0-38.95%, bulk density 0.39-0.59 g/ml, water absorption 115.20-383.70 g/100g, fat absorption 138.3-302.9 g/100g and free fatty acids 5.20-13.73%. All brans had pleasing flavour. Significant variations were observed with regard to colour of brans. The presence of anti-nutritional factors in brans is one of the major drawbacks, limiting their nutritional and food quality. Phytic, trypsin inhibitor, oxalates, tannins and polyphenols are the major undesirable constituents which restrict direct utilization of brans in diet. An attempt has been made to assess the presence of anti-nutritional components in different cereal brans. All cereal brans had a wide range of phytic acid (27.69-42.82 mg/g). Cereal brans have total polyphenols in the range of 0.54-6.53 mg/g and the content of tannins ranged 0.70-6.23 mg/g in brans. High oxalate content was observed in rice bran and minimum in oat bran (0.309 to 0.445%). Oat bran had a minimum amount of saponin, while a higher concentration of saponins were found in rice bran (1.99 to 3.30 mg/g). Trypsin inhibitor activity was 49.74-54.25 TIU/g. These factors can be eliminated by giving different stabilization treatments. De-fatting treatment given to cereal brans using hexane as solvent represented a marginal decrease in anti-nutritional components in all cereal brans.

Keywords: wheat, rice, barley, oats, dietary fibre, protein, physico-chemical composition, water absorption, India.

Introduction

Bran, an outer layer of most cereal grains, is nutrient dense as it contains proteins, omega 3 and omega 6 fatty acids and antioxidants. Cereal bran is an excellent source of dietary fibre; for addition to food, it offers all the nutritional and nutraceutical benefits of whole grain [1]. Brans are generally composed mainly of insoluble cellulose and hemicelluloses, with only about 5% soluble

fibre and have little hypercholesterolemia effect [2]. Bran contributes a pleasing sweet, nutty flavour when added as a flavour enhancer in baked products and pasta. Rice bran is rich in protein, lipids, fibre, minerals (Mg, K, Fe and Mn), B-vitamins and an excellent source of choline and inositol [3]. Barley contains a high level of soluble dietary fibre, making it a desirable food component for health benefits.

Anti-nutritional factors in different cereal brans limits their potential as a food source. Phytic, trypsin inhibitors, oxalates, tannins, polyphenols, heamagglutinin and lectins are the important undesirable constituents which restrict the straight-away utilization of brans in the diet. Rice bran has higher phytic content than wheat bran, corn bran and soy bran and oat hulls. Rice bran contains about 69% of the dietary fibre content of brown rice. Pigmented rice may be high in tannins, which are concentrated in the bran during milling [4]. Wheat bran is an important dietary fibre source, containing significant amounts of phytate, which has been reported to impair mineral retention under certain dietary circumstances. An extensive literature survey reveals that all these non-nutritional components are protein in nature, with the exception of phytate. To achieve effective utilization of brans for human nutrition, removal/elimination of these undesirable attributes is necessary. Processing treatments such as extrusion cooking, wet, dry, microwave heating and chemical methods can be used for elimination of undesirable components and for bran stabilization and the effect of the soluble oxalate intake could be mitigated by the consumption of high calcium food at the same time. Considering the nutritional, food potential and associated health benefits of consuming cereal brans the present investigation was planned to assess the physico-chemical, functionality and extent of anti-nutrients in both full fat and defatted cereal brans.

Materials and Methods

Raw materials

Wheat bran was collected from Ludhiana Flour Mill, Ludhiana. Rice bran was purchased from A.P. Solvex Pvt. Ltd., Dhuri and Punjab, India. Barley bran was prepared by milling of barley in grain pearler (CIAE, Bhopal). Oat bran (Baggry's India Ltd., New Delhi, India) was purchased from local market. De-fatting of brans was achieved by treating with cold hexane (food grade). The grinding of dried cereal brans was done to a uniform particle size using Cemotec mill (Foss, Hoganas, Sweden) having setting at No. 1.

Physico-chemical composition of raw materials

Approved methods were used to determine protein (N X 6.25) (method 46-10.01) and ash (method 08-01) for cereal brans [5]. Fat content was determined using a Foss Soxhlet extraction with petroleum ether [5]. Dietary fibre was estimated by extracting with neutral detergent solution as prescribed by Robertson and Van Soest [6]. Crude fibre of raw materials was estimated using Fibretec (Foss Company). Percentage carbohydrates were determined as (100 - % estimated proximate components). Calorific value (KJ/100g) was calculated by Bomb Calorimeter (Parr Instrument Company).

Functional characteristics

Bulk density (weight per unit volume) of cereal brans were determined by the method of Egan *et al.* [7]. Water absorption capacities of cereal brans were measured by the method as reported by Sosuliski [8]. Two gram sample of cereal brans was dispersed with 20 ml of water in a 50 ml centrifuge tube and allowed the mixture to stand for 15 min at 25°C then centrifuge the samples at 3200 rpm for 15 min. The amount of water retained by the solids was measured. Fat absorption of

cereal brans were estimated by mixing 2 g sample with 20 ml refined oil allowing the mixture to stand for 15 min at room temperature and then centrifuging at 3200 rpm for 15 min. The fat retained by the solids was measured by the method of Lin *et al.* [9]. Colour analysis was done by using Hunter Lab Colorimeter, MiniScan XE Plus (Hunter Lab, Reston, Virginia). Colour readings were expressed by Hunter values for L, a, and b. L values measure black to white (0-100); + a = red, - a = green; + b = yellow; - b = blue. Flavour of the brans was observed visually through a panel of semi-trained judges [10]. Water activity was estimated using water activity meter having HygroLab 3 bench-top indicator (Rotrogenic Company) and standard AOAC procedures [11] were followed for free fatty acids determination in cereal brans. 1g sample was taken in flask. 50 ml benzene was added and kept for 30 min for extraction of free fatty acids. 1 ml extract was taken in flask to which 5 ml benzene, 10 ml alcohol and phenolphthalein as indicator was added and titrated against 0.02 KOH till light pink colour disappeared.

Analysis of anti-nutritional compounds

The anti-nutritional compounds such as phytic acid [12], total polyphenol [13], tannins [5], oxalates [14] and saponins [15, 16] were quantified. Trypsin inhibitor activity was determined by the enzyme assay of Hajela *et al.* [17] by using benzoyl-DL-arginine-p-nitroanilide (BAPNA) as a substrate. One trypsin inhibitor unit (TIU) has been expressed as an increase of 0.01 absorbance units per 10 ml of reaction mixture at 410 nm. Trypsin inhibitor activity has been defined in terms of trypsin units inhibited per g protein.

Statistical analysis

The data were statistically analyzed as described by Snedecor and Cochran [18].

Results and Discussion

Analysis of raw materials

Proximate composition of the raw materials used is presented in Table 1. The protein content of cereal brans ranged from 9.6 – 15.03%. Rice and barley brans had 11.86 and 11.93% protein respectively. The lipid content was highest for rice bran and it ranged from 4.07 – 19.31%. Rice bran exhibited the most concentrated source of dietary fibre (38.90%) among all cereal brans. Barley bran had the maximum value for crude fibre (14.9%). Maximum ash content (6.72%) was observed in rice bran. Results for proximate composition (Table 1) indicated that defatted cereal bran samples contained 10.34 to 15.39% crude protein, 1.98-8.46% ash, 2.11 to 3.44% fat, 18.31-34.72% dietary fibre, 4.47-13.91% crude fibre and 50.83-62.05% carbohydrates. Significantly higher dietary fibre was determined in defatted wheat (34.72%) and oat (21.22%) brans. Similar results have been reported by Khan *et al.* [19] for defatted rice bran samples on dry weight basis.

Functional characteristics

Functional characteristics of cereal brans are as summarized in Table 2, bulk density of defatted cereal brans was less as compared to full-fat brans. On the whole, bulk density of particular brans ranged between 0.25g/ml to 0.59g/ml. Significant variability was observed with respect to water absorption of cereal brans. Water absorption of brans varied from 148.4 to 383.7g/100g. Wheat bran had the highest water absorption (383.7g/100g), James and Sloan [20] reported that the water absorption of edible stabilized rice bran were in the range of 182.2-213.1%. The variation in water absorption may be attributed to the source of bran and their processing conditions [21]. Among the two forms (fatted and defatted) of brans, wheat bran exhibited a different pattern for water and fat absorption. Defatted brans have higher water absorption than full fat brans. The hydrophobic nature

Table 1. Proximate composition* of different cereal brans.

Type of bran	Crude protein (%)	Ash (%)	Fat (%)	Dietary fibre (%)	Crude fibre (%)	Carbohydrates (%)	Calorific value (KJ/100g)
Full fat							
Wheat bran	9.6	4.06	4.1	33.4	7.75	60.5	1694
Rice bran	11.8	6.72	19.3	38.9	11.5	36.6	1973
Barley bran	11.9	3.07	4.2	22.6	14.9	51.8	1780
Oat bran	15.0	1.45	10.6	14.0	3.31	55.6	1912
LSD (p<0.05)	0.07	0.24	0.12	0.18	0.05	0.06	1.33
Defatted							
Wheat bran	10.3	4.68	2.89	34.7	8.03	60.1	1635
Rice bran							1494
	11.7	8.46	3.44	38.8	11.5	50.8	
Barley bran	12.5	2.95	2.78	18.3	13.9	53.9	1691
Oat bran							1768
	15.4	1.98	2.11	21.2	4.5	62.0	
LSD (P < 0.05)	0.12	0.12	0.12	0.12	0.12	0.13	1.63
Rice bran							1494
	11.7	8.46	3.44	38.8	11.5	50.8	
Barley bran	12.5	2.95	2.78	18.3	13.9	53.9	1691
Oat bran							1768
	15.4	1.98	2.11	21.2	4.5	62.0	
LSD (P < 0.05)	0.12	0.12	0.12	0.12	0.12	0.13	1.63

*Expressed at 14% moisture level
Values are means of three replications

of fat, which might have contributed to the reduced water absorption of full-fat brans, while the hydrophilic nature of crude fibre might have contributed to the increased water absorption in the defatted bran samples [22]. Similar pattern was observed for fat absorption of different cereal brans. Defatted brans absorbed less fat as compared to full-fat brans.

Lightness value for wheat, rice, barley and oat brans were 58.93, 59.04, 57.21 and 52.84 respectively. Barley bran had more redness followed by oat bran. b^* values (yellowness) was highest in wheat bran, while lowest in barley bran. Rice bran was darker in colour and minimum colour was recorded in wheat bran (full fat), but in defatted brans maximum colour was observed in barley bran (75.95) and minimum in wheat bran (69.48). All cereal brans had a pleasant flavour. Significant variation was noticed in water activity content. Water activity ranged from 0.48-0.82 for full-fat brans and from 0.51-0.79 for defatted brans. The extent of free fatty acids in different cereal brans varied significantly (5.20-13.73%). Significantly lower percentage of free fatty acids was found in defatted brans. The rice bran exhibited significantly higher values for free fatty acids as compared to other brans. This has been attributed to the presence of active inherent lipase system of rice bran which hydrolyses the oil free fatty acids and glycerol and renders bran unfit for oil extraction and human consumption [20].

Table 2. Functional characteristics* of different cereal brans.

Type of bran	Bulk density (g/ml)	Water absorption (g/100 g)	Fat absorption (g/100 g)	Colour				Flavour	Water activity (a_w)	Free fatty acids (%)
				L*	a*	b*	Hue angle ($^\circ$)			
Full fat										
Wheat bran	0.37	383.7	302.9	58.9	3.57	15.8	70.6	8.35	0.82	7.12
Rice bran	0.36	148.4	139.2	59.04	3.45	15.1	77.1	6.40	0.50	13.7
Barley bran	0.25	324.1	268.6	57.2	3.91	14.8	75.2	6.25	0.50	9.14
Oat bran	0.59	115.2	138.3	52.8	3.86	15.3	75.8	9.10	0.48	5.2
LSD ($p < 0.05$)	0.06	1.87	1.85	1.90	0.06	0.59	1.88	0.12	0.11	0.13
Defatted										
Wheat bran	0.38	232.7	189.9	56.2	5.80	15.5	69.5	8.35	0.53	6.69
Rice bran	0.36	199.2	149.4	54.0	3.53	14.0	75.1	7.35	0.79	14.0
Barley bran	0.26	340.6	260.2	56.3	3.70	14.8	75.9	6.15	0.55	8.00
Oat bran	0.61	179.2	117.9	58.7	4.81	15.7	72.4	9.05	0.51	3.99
LSD ($p < 0.05$)	0.05	1.88	1.83	1.81	0.12	0.57	1.86	0.15	0.11	0.16

*Expressed at 14% moisture level
Values are means of three replications

Anti-nutritional factors

Table 3 illustrates the content of different anti-nutritional factors concentrated in different cereal brans. Among different anti-nutritional factors, phytic acid occurred within the range of 27.69-42.82 mg/g. This range is similar to that found in the literature [23]. The concentration of phytic acid obtained was higher in full fatted rice bran and lower in oat bran (full fat and defatted). Statistically significant variations were observed in oat bran and rice bran with regard to anti-nutritional factors of different cereal brans. Rice bran had highest amounts of phytic acid (42.82 mg/g) followed by wheat bran (41.74 mg/g). Phytic acid content for wheat bran in one reported study ranges from 25-58 mg/g. The phytic acid for oat brans was half that of wheat bran (20 mg/g) and higher (58 mg/g) than that for rice bran [23]. Raw oat, rice, wheat brans contained 1.42, 4.32 and 5.27% phytate, respectively [24]. Different studies have shown variability in the phytate content of cereal brans. The phytate content of raw rice bran has been reported to range from 2.59 to 5.46 [25] and 6.90% [26]. Hard red wheat bran has been reported to have 3.00% [26], 6.68% [27] and from 4.59 to 5.52% [28] phytate content. The variations in phytate content may be attributed to differences in milling extraction rate, genotype and environmental effects. Sharma *et al.* [21] reported value for phytic acid (29.33 mg/g) in raw rice bran.

Table 3. Anti-nutritional factors* in different cereal brans.

Type of bran	Phytic acid (mg/g)	Polyphenols (mg/g)	Tannins (mg/g)	Oxalates (%)	Saponins (mg/g)	Trypsin Inhibitor (TIU/g)
Full fat						
Wheat bran	41.7	3.20	2.89	0.44	2.65	54.2
Rice bran	42.8	5.80	0.70	0.44	3.30	53.8
Barley bran	40.3	6.53	3.40	0.32	3.17	50.4
Oat bran	27.7	0.54	6.23	0.31	1.99	49.7
LSD (p<0.05)	1.88	0.11	0.13	0.05	0.14	1.86
Defatted						
Wheat bran	36.8	2.78	2.22	0.32	2.41	53.0
Rice bran	34.9	4.22	0.58	0.17	3.02	53.8
Barley bran	37.6	6.16	2.73	0.21	2.95	50.4
Oat bran	27.2	0.50	5.17	0.16	1.90	49.7
LSD (p<0.05)	1.81	0.14	0.12	0.05	0.11	1.84

*Expressed at 14% moisture basis

Values are means of three replications

The study revealed that the values for polyphenols varied significantly in wheat, rice and barley brans in contrast to oat bran. According to Herrmann and Nagel [29] total phenolic compounds in rice varied from 71-87 mg/kg. Phenolic acid data reported for rice endosperm cell walls was 12,000 mg/kg esterified cinnamic acids [30]. Variation in total polyphenols might be due to the different selection of reference standards used in each study. Besides, the nature of samples in each study might also affect the phenolic acid values, e.g.: lower value expected in rice < rice bran < cell walls of rice endosperm. Referring to Gumal *et al.* [31], total polyphenols content (TPC) calculated as catechin in grains of three rye cultivars (Amilo, Rostockie and Agrikolo) was: 1.86; 2.14 and 2.11 mg catechin/ g d.m. respectively.

Tannins are concentrated mainly in the seed coat; preliminary de-hulling constitutes the simplest method for their removal. Significant differences in the tannin content were seen among rice, wheat, barley and oat bran. Tannin content (mg/g) of all the brans used ranged from 0.70-6.23 mg/g being minimum for rice bran (0.70 mg/g). Percentage of tannins in different cereals as reported by Juliano [32] are brown rice 0.1%, wheat 0.4%, maize 0.4%, rye 0.6%, millet 0.6%, barley 0.7 %, oat 1.1% and sorghum 1.5%.

Data in Table 3 revealed that rice bran exhibited the higher level of oxalates (0.445%) followed by wheat (0.442%), barley (0.325%) and oat bran (0.309%). More recently, Boontaganon *et al.* [33] mentioned that total oxalate contents of the individual bran samples analyzed ranged from 37.0 mg/100 g dry matter (DM) for oat bran to 392.7 mg/100 g DM for wheat bran flakes. The mean data showed that oat bran products contained the lowest level of total oxalate (67.2 mg/100 g DM) compared to rice bran (139.5 mg/100 g DM) and wheat bran (220.8 mg/100 g DM). The data suggests that a daily portion of bran products, particularly wheat bran, would supply a constant

intake of soluble and insoluble oxalate but this would be a relatively small intake compared to other oxalate containing food that may be eaten in the diet. The higher oxalate content in whole grain than in refined grain cereals suggested that oxalic acid is primarily located in the outer layers of cereal grains.

Significant differences were observed in different cereal brans with regard to saponin (mg/g) content. With regard to this, rice bran had higher saponin content (3.30 mg/g) than wheat bran (2.65 mg/g), barley bran (3.17 mg/g) while oat bran contained 1.99 mg/g of saponins. Onning *et al.* [34] reported that saponin content was significantly different between oat cultivars and ranged from 0.020 to 0.050% with a mean of 0.40% (dry matter basis). The fraction with the smallest particle size had the highest concentration of saponins. Soybean contains 0.1-0.5% saponins. Unheated and heated full fat soy-flours contain approximately 0.5% saponins [35].

Cereal brans differed significantly among each other in their trypsin inhibitor activity (TIU/g) with wheat bran having the highest content. The trypsin inhibitor activity occurred within the range of 49.74-54.25 TIU/g. Chitra and Sadasivam [36] found that whole grain of urd bean (*Vinga mungo*), contained 905 TIU/g. Khan *et al.* [37] reported TIA/g in rice bran was (8013.00 TIA/g). Approximately 85-95% of the trypsin inhibitor activity was in the embryo, 5-10% in the germ free bran, <1% in polish and none in milled rice [38]. It is obvious from the results that the defatted bran samples exhibited slightly lower values for anti-nutritional factors in cereal brans.

Conclusion

Bran is an excellent source of dietary fibre; for addition to food, it offers all the nutritional and nutraceutical benefits of whole grain. Study results reflect that all cereal brans analyzed (wheat, rice, barley and oat) have excellent functional properties such as bulk density, water absorption and fat absorption. Therefore cereal brans have been found to more effective in increasing the shelf life of products and also as aids in calorie reduction. However, the anti-nutritional factors present in cereal brans limit their potential as a low quality feed ingredient such as phytic acid, polyphenols, tannins, oxalates, saponins and trypsin inhibitors. The presence of anti-nutritional factors identified in this current study illustrated that these should not pose a problem to human health if the cereal brans are properly processed. In view of the overall proximate composition and functional characteristics, cereal brans can be explored as alternative source of nutrients (proteins, B-vitamin and minerals).

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