Effect of Variety and Growing Year on the Constituents of Durum Bran Fiber[1]

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ABSTRACT

Whole meal and bran from five varieties of durum wheat comparably grown during three years were studied to determine the fibrous composition of durum whole meal and of bran originating from milling durum wheat into semolina. The Southgate procedure for unavailable carbohydrates was modified to obtain the following values (mean percent ± standard deviation) for the components of dietary fiber in bran and in whole meal, respectively: water-soluble noncellulosic polysaccharides (NCP) 0.6 ± 0.3 and 0.2 ± 0.1; water-insoluble NCP 23.6 ± 1.6 and 6.7 ± 0.3; cellulose 10.4 ± 0.9 and 2.7 ± 0.2; and lignin 3.6 ± 0.4 and 0.6 ± 0.1. In addition, the effects of variety and growing year were calculated. Variety and growing year significantly affected protein, ash, insoluble dietary fiber, percent extraction by 85% methanol, starch, water-insoluble NCP and cellulose contents in bran, and protein, ash, crude fat, and cellulose contents in whole meal. Variety had a significant effect on crude fat content in bran and on the insoluble dietary fiber content of whole meal. Growing year had significant effects on the water-soluble NCP content of bran, and on the lignin and percent extraction by 85% methanol in whole meal.

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During the past 15 years, awareness of the importance of fiber in the human diet has increased. Most of the fiber in cereal grains originates in the bran, which is the relatively indigestible outer protective coating of the grain. The endosperm is almost entirely digestible. Because cereal brans are used in the production of some breakfast cereals and variety breads, and because the different constituents of fiber may have different biological functions, the relative amounts of the various fiber constituents of cereal brans need to be determined. Several authors have reported values for the fibrous components of wheat bran. The sources of bran used for some of the studies have included hard red spring, hard red winter, soft red winter, soft white spring, and soft white winter wheats. Complete values for durum wheat have not been reported.

As a scientific term, wheat bran refers to the combination of pericarp and testa. As a commercial term, it refers to the mixture obtained as a result of milling, which consists of pericarp, seed coat, aleurone layer, small amounts of starchy endosperm, and, depending on the milling technique, various amounts of germ. The purposes of this study were to determine the fiber composition of durum wheat bran resulting from the milling of durum wheat into semolina and to determine whether varietal differences exist and to what extent different growing years affect the fibrous constituents.

MATERIALS AND METHODS

Samples and Sample Preparation

Fifteen wheat samples consisting of five varieties of durum comparably grown during three years at the North Central Experiment Station, Minot, ND, were used. Each of the samples was obtained from field-plot studies in which four replicates were combined to form a bulk composite following combine harvesting. The varieties used here were Cando, Crosby, Rolette, Rugby, and Vic, which were grown in 1977, 1978, and 1980. In addition to these 15 samples, one sample of Aldura, grown in Arizona, was included for comparative purposes but was excluded from the statistical analyses.

Whole meal. A Thomas-Wiley mill (intermediate model) equipped with a 20-mesh wire screen was used to grind cleaned wheat into whole meal. The whole meal was freeze-dried for 40 hr to reduce its moisture level and was refrigerated until analyzed.

Bran. Cleaned wheat was milled on a Buhler experimental mill that had been specifically modified for the milling of durum wheat into semolina (Seyam et al 1974). Because this mill yielded only one feed stream that contained bran, shorts, and low-grade semolina, the bran needed to be separated from shorts and small-particle residue by shaking over a tinned mill 18-wire screen. The bran was freeze-dried for 4 hr, ground on the Thomas-Wiley mill, and refrigerated until analyzed.

Bran and Whole Meal Analyses

Protein, ash, crude fat, moisture, and insoluble dietary fiber were determined by AACC (1962) procedures 46-11, 08-01, 30-25, 44-11, 44-15, and 32-20.

Fiber Fractionation

Three portions of each of the bran and whole meal samples were fractionated through the use of Southgate's method for unavailable carbohydrates (Southgate 1981), with the following modifications: starch was degraded using amyloglucosidase (Sigma no. A-7255) following gelatinization in a boiling water bath for 20 min; water-solubles were extracted with three portions of hot water; and monosaccharides were measured using modified anthrone, carbazole, and orcinol colorimetric reactions (Kunerth and Youngs 1984).

Data Manipulations

The concentration of hexoses, pentoses, and uronic acids in the original wheat products were calculated from the solution concentration, using appropriate dilution factors, the original sample weight, and a factor to convert monosaccharides to polysaccharides. Significant differences ($P = 0.05$) were determined through the use of Duncan's multiple range test.

RESULTS AND DISCUSSION

Although this study included analyses for the more commonly measured constituents such as protein, ash, crude fat, and insoluble dietary fiber, the main emphasis was on the fractionation of fiber and quantitation of water-soluble noncellulosic polysaccharides (NCP), water-insoluble NCP, cellulose, and lignin. The Southgate method for unavailable carbohydrates was modified and used to obtain quantitative values for the components of fiber.

Although widely used, the Southgate method has inherent

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problems, the significance of which depends on the material being analyzed. Many of the problems are discussed in a recent text (James and Theander 1981). The process for removal of starch by gelatinization in a boiling water bath for 10 min followed with hydrolysis by amyloglucosidase is considered to be inadequate by several researchers because incomplete gelatinization may result from this mild treatment. Some of the critics suggest autoclaving at 130° C for 60 min, but others are concerned that autoclaving might induce changes in the fiber. As a compromise, the gelatinization treatment used consisted of treatment in a boiling water bath for 20 min. The average starch concentration observed in the bran of 15 durum samples was 15.7%. Coefficients of variation (CV) based on triplicate determinations were calculated for each sample. The average CV for the bran samples was 3.5%. For the 15 whole meal samples, the average starch concentration was 60.9% with an average CV of 3.4%.

Also of concern with respect to removal of starch is the specificity of the amyloglucosidase used. An enzyme from *Rhizopus* mold was used (Sigma A-7255). The enzyme was tested for hemicellulase and pectinase activity by analyzing the supernatants resulting from amyloglucosidase treatment of bran and whole meal samples that had been previously extracted with 85% methanol and acetone; pentoses and uronic acids were measured using the modified orcinol and carbazole reactions. The analyses failed to detect pentoses or uronic acids. In addition, the supernatants were analyzed for neutral sugars using the gas-liquid chromatography (GLC) procedure of Medcalf et al (1968). Glucose was the only sugar detected.

The anthrone, carbazole, and orcinol methods for quantitation of hexoses, uronic acids, and pentoses were evaluated for specificity and found to be inadequate. The procedures were modified, with the details published elsewhere (Kunerth and Youngs 1984).

To evaluate the modifications to Southgate's method, total recoveries were calculated as the sum of water-soluble NCP, water-insoluble NCP, cellulose, lignin, protein, ash, starch, and percent extracted by 85% methanol. The average total recoveries were 96.9% for bran and 99.2% for whole meal. The standard deviations for total recovery were 1.7% for bran and 2.3% for whole meal. Total fiber contents were calculated as the sum of water-soluble NCP, water-insoluble NCP, cellulose, and lignin. The values for total fiber were compared to the values obtained using the AACC method for insoluble dietary fiber. The mean values obtained for bran were 38.1% from the fractionation method and 39.3% from the AACC method; for whole meal, the mean values were 10.2% and 9.4%. A highly significant correlation ($P = 0.01$, $r = 0.997$) was observed between the two methods.

Analysis of variance procedures were conducted on the bran and whole meal data, using fixed model techniques. A summary of the data is shown in Table I. Variety and growing year had a highly significant ($P = 0.01$) effect on the protein, ash, insoluble dietary

TABLE I
Summary of Data

Constituent Mean ± SD[a] (%)[b]	Overall Range ($n = 15$)	Variety (A)[c] Range ($n = 5$)	Variety (A)[c] PR>F[d]	Growing Year (B)[e] Range ($n = 3$)	Growing Year (B)[e] PR>F[d]	A × B PR>F[e]	Aldura (%)[a]
Protein							
Bran 19.2 ± 1.3	17.2–21.7	18.1–20.4	0.0001	18.0–19.9	0.0001	0.0001	14.7
Whole meal 17.6 ± 1.2	15.8–20.6	16.6–18.7	0.0001	16.4–18.6	0.0001	0.0001	11.3
Ash							
Bran 5.8 ± 0.7	4.9– 6.9	5.5– 6.1	0.0001	5.2– 6.7	0.0001	0.0001	5.2
Whole meal 1.9 ± 0.2	1.7– 2.1	1.8– 1.9	0.0001	1.7– 2.1	0.0001	0.0013	1.7
Crude fat							
Bran 7.5 ± 0.3	7.0– 8.0	7.1– 7.8	0.0001	7.5– 7.6	0.7390	0.0001	6.9
Whole meal 2.0 ± 0.1	1.8– 2.1	1.9– 2.0	0.0005	1.9– 2.0	0.0042	0.4406	1.6
Insoluble dietary fiber							
Bran 39.3 ± 2.1	34.2–42.6	36.8–41.2	0.0001	38.1–40.4	0.0001	0.0001	38.7
Whole meal 9.4 ± 0.3	8.9–10.1	9.1– 9.7	0.0104	9.2– 9.5	0.0836	0.1687	9.4
Percent extracted by 85% methanol							
Bran 18.1 ± 0.9	16.8–19.3	17.1–18.9	0.0001	17.7–18.7	0.0001	0.0015	18.8
Whole meal 8.6 ± 0.6	7.7– 9.4	8.3– 8.8	0.1994	8.2– 9.0	0.0022	0.0088	9.0
Starch							
Bran 15.7 ± 1.4	14.0–18.7	14.9–17.0	0.0001	15.2–16.8	0.0001	0.0034	18.9
Whole meal 60.9 ± 1.9	57.3–64.2	60.1–62.5	0.2208	60.7–61.0	0.8971	0.0158	62.6
Water-soluble NCP[f]							
Bran 0.6 ± 0.3	0.4– 1.4	0.4– 0.8	0.1384	0.5– 0.8	0.0166	0.1356	0.3
Whole meal 0.2 ± 0.1	0.1– 0.3	0.2– 0.2	0.8952	0.2– 0.2	0.2302	0.9795	0.2
Water-insoluble NCP[f]							
Bran 23.6 ± 1.6	20.5–26.8	21.7–24.4	0.0001	22.0–23.7	0.0002	0.0270	25.7
Whole meal 6.7 ± 0.3	6.1– 7.1	6.5– 6.8	0.3832	6.5– 6.7	0.0016	0.2462	7.5
Cellulose							
Bran 10.4 ± 0.9	9.6–13.2	10.3–12.1	0.0001	10.4–11.6	0.0008	0.1945	10.0
Whole meal 2.7 ± 0.2	2.6– 3.1	2.6– 2.9	0.0014	2.6– 2.9	0.0018	0.2580	2.9
Lignin							
Bran 3.6 ± 0.4	3.3– 4.5	3.3– 4.0	0.1148	3.3– 3.8	0.1275	0.6005	3.2
Whole meal 0.6 ± 0.1	0.4– 0.9	0.6– 0.7	0.6457	0.5– 0.7	0.0085	0.1427	0.4
Total fiber							
Bran 38.1 ± 2.4	34.9–42.7	36.0 –40.5	0.0001	36.1–39.4	0.0001	0.0967	39.3
Whole meal 10.2 ± 0.5	9.4–11.0	9.95–10.5	0.5016	10.0–10.5	0.1194	0.2165	11.0

[a] Mean ± standard deviation, $n = 15$.
[b] Percent dry basis.
[c] Includes the range of variety values for the constituent being considered and the significance probably used in determining whether variety had a significant effect on the constituent in question. The varietal ranges were based on five varieties; each variety's value was the mean of three years.
[d] The significance probability (PR > F) is the probability of an F value larger than the calculated F value; when PR > F is less than the preselected value (0.05 or 0.01), the analysis of variance F value was significant or highly significant.
[e] Includes the range of growing year values for the constituent being considered, and the significance probability used in determining whether growing year had a significant effect on the constituent in question. The growing year ranges were based on three growing years; each year's value was the mean of five varieties.
[f] Noncellulosic polysaccharides.

fiber, percent extracted by 85% methanol, starch, water-insoluble NCP, cellulose, and total fiber contents in bran, and on the protein, ash, crude fat, and cellulose contents of whole meal. Variety had a highly significant effect on the crude fat content of bran and a significant ($P = 0.05$) effect on the insoluble dietary fiber content of whole meal. Growing year had a significant effect on the water-soluble NCP content of bran and a highly significant effect on the lignin and on the percent extracted by 85% methanol in whole meal. Highly significant correlations were observed between the bran and whole meal data for protein, ash, and crude fat. No significant correlations were observed between the bran and whole meal data for any of the other constituents measured.

The effects of variety and growing year on the fibrous components were much more pronounced for bran than for whole meal. This was probably caused by a combination of two factors. First, the proportion of fibrous components in whole meal was much smaller than in bran. Thus, measurement of the minor components was much more difficult because of the decreased concentration. Second, because all samples were milled comparably, the concentration of starch in the bran sample was determined by the milling characteristics of the individual wheat samples. The variation of starch concentration in the bran affected the concentrations of fibrous components through a dilution effect.

When the fibrous components of the five varieties were evaluated, Cando either had the highest mean concentration of each component averaged over three years or was not significantly different ($P = 0.05$) from the variety that had the highest for both the bran and whole meal samples. Crosby had the lowest mean concentration or was not significantly different from the variety that had the lowest.

In evaluating the three growing years with respect to fibrous components, 1978 either had the highest mean concentration of each component averaged over five varieties or was not significantly different from the year that had the highest for the bran samples. The lowest concentrations were either observed in the 1977 samples or the year producing the lowest concentration did not differ significantly from the 1977 samples. The results from the whole meal samples were similar to the bran samples, with 1978 showing higher values and 1977 showing lower values for all fiber constituents, except cellulose, when significant differences were observed. With respect to weather conditions, the available data were limited to average monthly temperature and total monthly precipitation; as a result specific conclusions could not be drawn. However, 1977 was observed to have the highest average monthly temperature and the highest annual precipitation of the three years.

Also shown in Table I are the mean results obtained from triplicate analyses of the Aldura sample grown under irrigation in Arizona. Because the results of the Aldura sample were not included in the statistical evaluation, no specific conclusions could be drawn concerning differences between durums grown in the southwest and durums grown in North Dakota. However, no drastic differences were observed, except for the lower protein content of Aldura.

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