Relative Lipidemic Responses in Rats Fed Barley and Oat Meals and Their Fractions[1]

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ABSTRACT

Whole meal, bran, and flour from three barley genotypes, which contained graded levels of soluble fiber, were compared with similar commercial fractions of oats for their effect on blood cholesterol (CH), triglycerides, high-density lipoprotein (HDL) CH, and liver CH (test model, using hypercholesterolemic rats). Whole meals of the three barley genotypes contained 3.0, 5.2, or 6.8% soluble fiber; oatmeal contained 3.0%. In meal-fed rats, barley genotypes did not show a favorable blood or liver lipid response compared with oats. However, in bran- and flour-fed rats, the data showed that barley exerted a profound blood and liver CH-lowering effect compared with oat bran or flour (blood triglyceride levels were minimally affected). Blood HDL-CH levels were appreciably elevated in rats fed barley bran or flour compared with oat bran or flour. These results suggested that barley and its major fractions (bran and flour) may evoke different lipidemic responses and that barley bran and flour have a more favorable effect on blood lipids than do oat bran and flour.

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Barley and oats are unique among cereals containing high concentrations of the nonstarchy polysaccharides, β-glucans, in endosperm cell walls. The concentration of these glucans in barley is reported to range between 3.0 and 6.9%, and that in oats between 2.2 and 4.2% (Aman and Graham 1987). Two-rowed barley genotypes are generally richer in β-glucans (Lehtonen and Aikasalo 1987), although a six-rowed, waxy, hulless barley contains about 11%.

Soluble β-glucans are a major component of soluble fiber (SF) (Frolich and Nyman 1988). In both men and animals, SF has been reported (Behall et al 1984, Anderson et al 1984, Pilch 1987, Ranhotra et al 1987, Klopfenstein and Hoseney 1987, Newman et al 1989) to lower elevated blood cholesterol (CH), a risk factor in heart disease.

The bran fraction of barley, which may be dry milled to yield 70% flour and 30% bran, may contain 1.5 times more β-glucans than the whole meal. Barley bran, like other cereal brans, has many food applications but has not been studied like oat, wheat, and rice brans, nor have its lipidemic effects been investigated. Barley bran may be a potent hypocholesterolemic agent because of its high SF content. This study was undertaken to examine this possibility; for comparison, barley meal and flour were also studied concurrently. These products were compared with similar commercial oat products, using hypercholesterolemic rats as the test model.

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MATERIALS AND METHODS

Test Samples

Three hulless barley genotypes (Scout, two-rowed; line 85751 waxy, two-rowed; and Arizona waxy, six-rowed) containing low, medium, and high levels of β-glucans were first milled into meal with a Udy cyclone mill (0.5-mm screen). Larger samples of the grain were dry milled into bran and flour fractions in an Allis-Chalmers experimental mill. As described earlier (Bhatty 1987), the milling process consists of three breaks, three reductions, and six sifting steps. The three flour fractions—break, reduction, and clear—were combined to obtain flour, and the shorts and bran fractions were combined to obtain bran. Oat meal, bran, and flour were obtained from Robin Hood Multifoods, Inc., Saskatoon (variety unknown). Table I lists the compositional information on these samples.

Test Diets

A total of 12 diets were formulated containing 75% meal, bran, or flour from oats and each of the three barley genotypes (Table II). Diets were complete in all nutrients required by rats (NRC 1987). All diets contained added CH and cholic acid to induce hypercholesterolemia in the animals.

Animals

Twelve groups of male weanling rats (10 rats/group) of Sprague-Dawley strain (Harlan Sprague-Dawley, Indianapolis, IN) were housed individually in suspended mesh-bottom, stainless steel cages in a controlled environment. Each rat was allowed to consume an adequate but equal amount (pair-feeding) of total diet over the six-week test period. Deionized water was offered ad libitum. Body weight records were maintained.

TABLE I
Chemical Composition of Test Material

Material	Components (g/100 g)							
	Moisture	Protein (N × 5.7)	Fat	Ash	TDF[a]	SF[b]	Carbo-hydrates	β-Glucans (g/100 g)
Meal								
Oat	10.1	14.1	7.7	1.7	8.9	3.0 (34)	57.5	3.9
Barley								
Scout	12.0	11.7	3.1	1.7	11.3	3.0 (27)	60.2	4.1
85751	10.3	14.0	3.1	1.8	14.2	5.2 (37)	56.6	7.2
Arizona	10.2	11.7	4.1	2.1	20.1	6.8 (34)	51.8	9.8
Bran								
Oat	10.3	17.6	8.4	2.5	12.5	4.2 (34)	48.7	6.9
Barley								
Scout	8.5	16.5	4.1	2.6	18.4	6.4 (35)	49.9	6.5
85751	8.8	14.4	3.1	1.8	15.7	7.3 (47)	56.2	9.9
Arizona	9.4	11.2	3.4	2.0	21.9	12.5 (57)	52.1	13.2
Flour								
Oat	9.4	11.9	7.6	1.4	5.2	1.6 (31)	64.5	2.7
Barley								
Scout	10.4	10.8	2.5	1.1	5.3	2.3 (43)	69.9	3.2
85751	8.8	14.0	4.0	1.7	10.8	4.9 (45)	60.7	6.2
Arizona	9.6	11.5	4.1	1.8	12.6	6.8 (54)	60.4	8.0

[a] Total dietary fiber.
[b] Soluble fiber; values within parentheses represent SF as a percentage of TDF.

TABLE II
Test Diets[a]

Material[b]	Diet	Ingredients (g/100 g)				TDF[e] (%)	SF[f] (%)
		Oil[c]	Gluten	Others[d]	Cornstarch		
Meal							
Oat	A	0.70	3.76	8.33	12.21	6.7	2.3
Barley							
Scout	B	4.07	6.30	8.33	6.30	8.5	2.3
85751	C	4.16	3.84	8.33	8.67	10.6	3.9
Arizona	D	3.37	6.37	8.33	6.93	15.1	5.1
Bran							
Oat	E	0.19	...	8.33	16.48	9.4	3.1
Barley							
Scout	F	3.41	1.16	8.33	12.10	13.8	4.8
85751	G	4.12	3.50	8.33	9.05	11.8	5.5
Arizona	H	3.88	6.89	8.33	5.90	16.4	9.4
Flour							
Oat	I	0.72	6.10	8.33	9.85	3.9	1.2
Barley							
Scout	J	4.51	7.34	8.33	4.82	4.0	1.7
85751	K	3.47	3.87	8.33	9.33	8.1	3.7
Arizona	L	3.37	6.53	8.33	6.77	9.5	5.1

[a] All diets contained 6.5% fat and 15% protein.
[b] Each diet contained 75 g of material per 100 g.
[c] Soybean oil.
[d] Included (g/100 g of diet): vitamin mix, 1; mineral mix, 3.5; casein, 2.13; L-lysine, 0.5; cholesterol, 1; and cholic acid, 0.2.
[e] Total dietary fiber.
[f] Soluble fiber.

Blood Sampling

At weeks 2, 4, and 6, rats were fasted overnight (14 hr), then lightly anesthetized, and 2.0 ml (1.0 ml at week 2) of blood was withdrawn by heart puncture. The blood was allowed to clot and then centrifuged prior to obtaining the serum. Lipid analyses were run on the refrigerated serum the next day. At week 6, rats were sacrificed and their livers were removed, blotted dry, weighed, and homogenized in water medium. The homogenate volume was recorded, and a suitable aliquot was saved (frozen) for CH determination.

Analytical

AACC approved methods (AACC 1983) were used to analyze test samples for protein (Kjeldahl), fat (acid hydrolysis), and ash. β-Glucan content was determined by the procedure of McCleary and Glennie-Holmes (1985). Moisture was determined under vacuum (16 hr, 70°C, 25 mmHg). Total dietary fiber (TDF) and SF contents were determined by the method of Prosky et al (1988). Total and high-density lipoprotein (HDL) CH in serum were determined enzymatically using kit no. 352 from Sigma Chemical Co., St. Louis, MO; HDL-CH was determined following magnesium dextran sulfate precipitation of nonHDL-CH fractions. Serum triglycerides were also determined enzymatically using kit no. 336 from Sigma. Total CH in liver homogenate was determined by the method of Abell et al (1952).

Statistical

Mean comparisons were made with Duncan's multiple-range test using the Statistical Analysis System (SAS 1982).

RESULTS AND DISCUSSION

Soluble Fiber and Glucans in Samples

To enable possible quantitation of lipidemic responses, the three barley genotypes were chosen to represent graded levels of both SF (3.0, 5.2, or 6.8%) and β-glucans (4.1, 7.2, or 9.8%) (Table I). These gradation differences in SF and glucans persisted in the resultant bran and flour fractions. SF was not analyzed for the content of soluble β-glucans, but soluble glucans likely represented the major component of SF (Frolich and Nyman 1988).

Barley bran contained more SF than barley meal; bran was a relatively richer source of SF (compared with TDF) due to β-glucan concentration on milling. In contrast, barley flour contained less SF than barley meal, but like bran, it was also a richer (compared with TDF) source of SF. The contents of SF in oat meal and its bran and flour fractions were proportionally more uniform. Barley bran and flour easily contained more than one-third of the TDF as SF, more than in oat bran and flour. In the barley and oat meals, SF/TDF ratios were generally similar; the barley genotype Scout was an exception, however.

Soluble Fiber in Test Diets

With one exception (diet B), barley-based diets contained more SF than the corresponding oat-based diets; differences were particularly significant with regard to the barley genotype Arizona (Table II).

Diet Intake and Weight Gains

To minimize variables other than SF that might affect blood lipid levels, diets were equalized to contain the same levels of fat and protein (type of fat differed minimally between diets as did quality of protein). They were also offered in amounts to ensure adequate, but nearly identical, consumptions (Table III).

This way, the dietary CH intakes were also identical.

Excluding the group of rats fed diet C (study curtailed at week 4 due to lack of test material), rats fed the other 11 diets averaged a body weight in the range of 215–248 g. The lower body weights on some of these diets primarily resulted from lower caloric densities (diets contained more TDF).

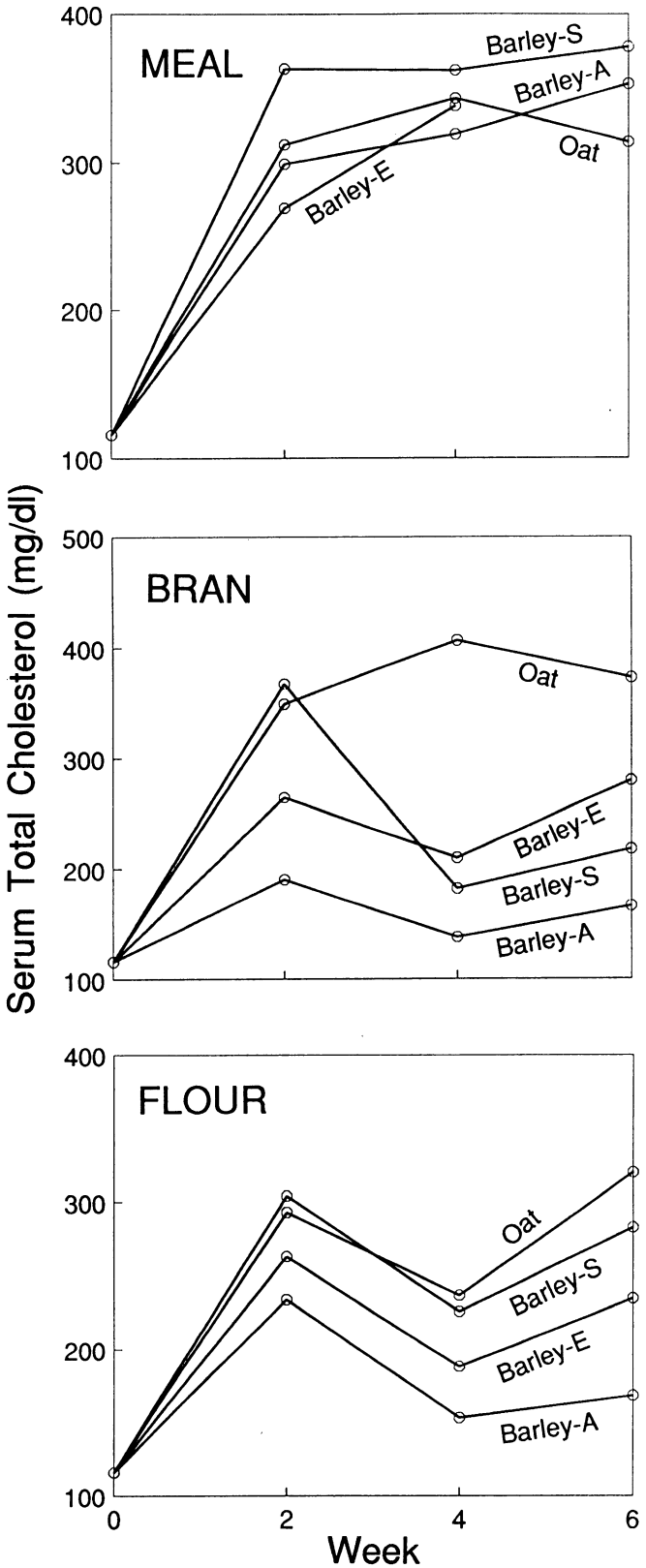

Fig. 1. Lipidemic responses in rats fed diets based on whole meal, bran, or flour. Barley genotypes tested are identified as barley-S (Scout), barley-E (85751), and barley-A (Arizona).

Serum Total CH

Serum CH in normocholesterolemic rats rarely exceeds a level of 110 mg/dl. Feeding CH, however, elevates serum CH levels quite profoundly (Ranhotra et al 1990). This occurred in this study as well; serum CH levels at week 2 averaged between 190 and 367 mg/dl (Table III). Within this range, significant ($P < 0.05$) differences appeared that seemed to be related, at least for most diets, to the amount of SF in the diet. For example, rats fed the diet containing the highest level of SF (diet H; formulated with barley bran) showed the lowest serum CH levels throughout the six-week test period (Table III, Fig. 1).

Diets formulated with barley flours also revealed an inverse relationship between serum CH levels and dietary SF content (diets I–L). This was particularly true at weeks 4 and 6. In contrast, in rats fed meal-based diets (diets B–D), SF appeared to bear no relationship to serum CH levels. In fact, by week 6, serum CH levels were somewhat more elevated in rats fed barley meal than oat meal even though barley-based diets contained as much (diet B) or more (diet D) SF. In the chicken model, Qureshi et al (1980) reported a CH-lowering effect in barley due to a decrease in a rate-limiting enzyme in cholesterol synthesis; subsequently, the authors identified α-tocotrienol as an inhibitor of this enzyme. However, if human subjects respond like the rats used in this study, it would suggest that the ability of SF in barley meal to lower CH is negated by some mechanism (activation of β-glucanases, for example).

Serum Triglycerides

Elevated serum triglyceride (TG) levels are viewed by some as an independent risk factor in heart disease (Pilch 1987). Unlike serum CH levels, serum TG levels were not the lowest in rats fed diets highest in SF. This was true at week 2 and 4, although by week 6, TG levels were the lowest in rats fed the diets highest in SF, whether meal-, bran-, or flour-based. Viewed collectively, the TG responses suggest that SF in barley may have a minimal desired effect, if at all, on serum TG levels.

Serum HDL Cholesterol

Elevated serum HDL-CH levels, unlike total CH levels, are reported (Anderson et al 1984, Pilch 1987) to provide protection against heart disease. In meal-fed animals, barley-based diets did not show a noticeable increase in HDL-CH compared with the oat-based diet. In bran- and flour-fed animals, however, an interesting pattern again emerged. With one exception (Table III), HDL-CH levels in barley-fed rats were appreciably higher, significantly ($P < 0.05$) so in most cases, compared with the oat-fed rats. In each (bran or flour) category, HDL-CH levels were most elevated in rats fed diets containing the highest levels of SF (diets H and L). This occurred at all three blood-sampling intervals.

Liver CH

Among the meal-fed rats (diets A–D), those fed barley-based diets showed significantly ($P < 0.05$) greater hepatic deposition of CH than those on the oat-based diet (Table III). Thus, barley meal not only failed to show a serum CH-lowering effect compared with oat meal, it also showed a greater hepatic deposition of CH. A contrasting picture emerged in bran- and flour-fed animals. In these animals, hepatic CH levels were, with one exception, appreciably lower in rats fed barley-based diets than those fed oat-based diets. This was true when CH content was expressed on a per unit basis (Table III) or as the total amount in the liver. Like serum total CH, hepatic CH content was the lowest in rats fed diets (bran- and flour-based) highest in SF.

Thus, it seems that the bran and flour fractions of barley genotypes that are rich in SF would likely exert a more favorable effect on blood lipids than such fractions from oats.

TABLE III
Physiological Responses in Rats Fed Oat or Barley Products[a]

Diet	SF[b] (%)	Weight Body (g)	Weight Liver (g)	Diet Intake (g)	Serum Total Cholesterol (mg/dl) Week 2	Serum Total Cholesterol (mg/dl) Week 4	Serum Total Cholesterol (mg/dl) Week 6	Serum Triglycerides (mg/dl) Week 2	Serum Triglycerides (mg/dl) Week 4	Serum Triglycerides (mg/dl) Week 6	Serum HDL Cholesterol[c] Week 2	Serum HDL Cholesterol[c] Week 4	Serum HDL Cholesterol[c] Week 6	Liver Cholesterol (mg/g)
Meal														
A	2.3	245±9a	14.1±0.8a	587±1	312±53abcd	343±58b	314±77ab	49±9c	63±10bc	71±13ab	5±2f	7±1f	9±3bcd	67±15cde
B	2.3	232±4b	13.7±1.0a	588±0	363±79ab	362±91ab	378±57a	52±10bc	63±11bc	75±18a	6±2ef	8±4ef	5±3d	84±10b
C[d]	3.9	191±7f	12.5±1.4b	378±0	269±63de	338±67b	...	68±9a	87±10a	...	10±2cdef	10±5ef	...	76±6bc
D	5.1	217±3de	11.1±0.8c	588±0	299±77bcde	319±72b	353±102ab	54±16bc	68±11bc	50±10c	15±7bc	14±10def	7±3bcd	100±16a
Bran														
E	3.1	234±6b	13.2±0.5ab	588±0	349±90abc	407±91a	373±70a	49±9c	65±10bc	77±17a	7±3ef	7±3f	6±2cd	65±25cde
F	4.8	225±5c	9.7±0.6de	584±0	367±77a	182±40cde	218±46cd	69±14a	57±16cd	54±11c	11±4cde	26±7ab	18±2a	54±13ef
G	5.5	223±7cd	10.4±0.7cd	571±0	264±65de	210±41cd	280±78bc	55±7bc	73±8b	55±10c	16±7b	18±8cd	12±5b	57±10def
H	9.4	222±5cde	9.0±0.7e	581±0	190±33f	138±16e	166±33d	55±14bc	64±10bc	49±9c	27±8a	32±6a	23±11a	45±5f
Flour														
I	1.2	248±4a	12.6±1.1b	587±0	293±78cde	237±44c	320±67ab	50±22c	65±14bc	72±13a	7±2ef	14±4de	9±5bcd	68±8cde
J	1.7	236±7b	10.9±0.7c	588±1	304±59abcd	226±54c	283±68bc	63±8ab	48±13d	59±14bc	9±4def	18±7cd	7±3bcd	71±15bcd
K	3.7	236±8b	11.4±1.4c	586±4	263±55de	188±55cde	235±24cd	54±7bc	66±6bc	50±13c	13±7bcd	21±11bc	11±3bc	54±7ef
L	5.1	215±6e	9.0±1.0e	582±0	234±53ef	153±36de	168±25d	59±8abc	59±12c	48±7c	16±7b	28±9a	23±6a	54±9ef

[a] Values are averages ± SD (7–10 rats per diet). Within a column, means not followed by the same letter are significantly different ($P < 0.05$).
[b] Soluble fiber.
[c] High-density lipoprotein cholesterol as a percentage of total cholesterol.
[d] Rats fed diet C showed data only up to four weeks; all other groups show data for the entire six weeks.

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