Effect of Fiber on Availability of Protein from Wheat Shorts

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ABSTRACT

The effect of the level and the particle size of fiber on the availability of protein from shorts was studied. On a 10% protein diet, the rate of growth and PER tended to be somewhat higher in rats fed ground shorts (70 mesh; fiber about 10%) and was much higher in those fed wheat protein concentrate (70 mesh; fiber about 3%) as compared to coarse shorts (15 mesh; fiber about 10%). Also, despite somewhat low lysine intake (0.83 vs. 0.88 g.), more nitrogen was retained by rats fed wheat protein concentrate than coarse shorts (116 vs. 100%). Between the coarse and ground shorts, rats fed ground shorts also retained more nitrogen (109 vs. 100%). Protein digestibility of the two shorts did not differ but it was significantly higher for wheat protein concentrate (83 vs. 71%). The pattern of plasma-free amino acids tended to reflect the quality of ingested protein more closely for wheat protein concentrate and ground shorts than for coarse shorts.

The shorts and bran fractions that resulted from commercial milling of wheat have been shown to be relatively high in protein (1,2) primarily because of the high concentration of aleurone cells (3). Moreover, their essential amino acid pattern compares favorably to that of animal protein (1,2). Lysine, whose relative inadequacy limits the quality of wheat protein for rapid growth in animals, is present in much higher amounts in shorts and bran than in whole wheat or wheat flour (1,2,4). However, it is conceivable that the high level of fiber in these fractions might interfere with the availability of amino acids to man and monogastric animals. This paper presents results on the biological availability of protein from shorts as it may be influenced by the level and the particle size of fiber.

MATERIALS AND METHODS

Wheat shorts and wheat protein concentrate (WPC; prepared by grinding and sifting shorts (4)) were obtained from Dixie Portland Mill in Chicago and Burrus Mill in Dallas, respectively. Shorts, first sifted to remove fine particles, was hammer-milled to two particle sizes, the finer one corresponding to that of WPC (Table I). Proximate analyses of shorts and WPC were carried out by standard methods (5). Amino acids, except tryptophan, were determined in an acid hydrolysate of protein with a Beckman-Spinco model 120 C amino acid analyzer. Samples were hydrolyzed by procedure B of Kohler and Palter (6), except that the hydrolysis was carried out for 16 hr. at 121° in an autoclave at 15 lb. pressure. Where applicable, necessary correction factors were used. Tryptophan was determined by the method of Tkachuk and Irvine (7).

Weanling male rats (Sprague-Dawley), averaging about 40 g. initially, were fed *ad libitum* the experimental diets (Table II) for 17 days. In all feeding experiments, diet was offered to the animals mixed with water. Food intake and weight gain records were kept on individual rats. On the 18th day all rats were sacrificed and their carcass nitrogen was determined by the method described earlier (8). Seventy-gram rats housed individually in metabolism cages were used in digestibility

TABLE I. PROXIMATE ANALYSES AND AMINO ACID COMPOSITION

Sample		Particle Size (U.S. Sieve) mesh	Protein (N X 5.7) %	Ether Extract %	Fiber %	Ash %	Moisture %
Shorts:	Coarse	15	15.45	5.14	9.57	5.07	10.61
	Ground	70	15.93	5.35	9.94	5.34	7.24
WPC		70	18.57	5.15	3.23	3.14	10.54

	Amino acids, g. / 16. g. N									
	Arg	His	Ile	Leu	Lys	Met[a]	Phe[b]	Thr	Trp	Val
Shorts	6.21	2.32	3.39	5.91	3.86	1.23(1.54)	3.64(2.29)	2.87	1.83	4.75
WPC	5.33	2.09	3.07	5.35	3.67	1.16(1.32)	3.46(2.00)	2.64	1.16	4.27

Amino acid values represent average of triplicate determinations.

[a]Cystine within bracket.

[b]Tyrosine within bracket.

studies. After a preliminary feeding of 6 days, fecal collections were made from each rat over the next 5 days. The pooled 5-day feces of each rat were dried, pulverized, and analyzed for protein content. Eighty-gram rats, trained by starvation to consume about 4 g. of dry diet in 10 min., were used to study the changes in plasma-free amino acids. Just prior to feeding and at 90 min. afterward, about 1 ml. of blood from each rat was drawn (heart puncture) into heparinized tubes. Blood samples were pooled according to diet group and processed by the method of Anderson and Linkswiler (9). Amino acids were determined on the analyzer by standard procedure for physiological fluids.

RESULTS

Proximate analyses of shorts and WPC are shown in Table I which also lists their essential amino acid composition. Tables III and IV summarize the results of feeding experiments. Rats fed WPC gained significantly faster ($P<0.05$) compared to those fed shorts. Between the coarse and ground shorts, rats fed ground shorts gained a little faster. On all test diets, the protein efficiency ratio (PER) obtained was distinctly higher than that reported for whole wheat; WPC-fed rats again showed a significantly higher ($P<0.05$) PER value than shorts-fed rats. As shown in Table III, at identical nitrogen and lysine intakes, rats fed ground shorts retained 9% more nitrogen than those fed coarse shorts. Nitrogen retention in WPC-fed rats was the highest, 116%, despite somewhat low lysine intake. No difference in protein digestibility between coarse and ground shorts was observed, whereas, compared to them, it was significantly higher ($P<0.05$) for WPC. The changes in the plasma-free amino acids of the rats fed the three test diets are shown in Table IV.

DISCUSSION

Though high in protein and in essential amino acids, wheat shorts shows poor

TABLE II. COMPOSITION OF TEST DIETS

Ingredients	Shorts		WPC
	Coarse %	Ground %	%
Shorts/ WPC	63.0	63.0	54.3
Vitaminized sucrose[a]	5.0	5.0	5.0
Salt 446[a]	4.0	4.0	4.0
NaCl	1.0	1.0	1.0
Corn oil[a]	4.0	4.0	4.0
Agar	3.0	3.0	3.0
Dextrin	20.0	20.0	28.7
	100.0	100.0	100.0
Protein (N X 5.7), %			
Calculated	9.8	10.0	10.0
Analyzed	9.9	10.2	10.0

[a]Reference 8. Vitamins were added to sucrose at three times the level.

protein utilization (10). Since a sizable part of the protein resides in the aleurone cells (3) whose cell walls are largely cellulosic (11), monogastric animals are perhaps not able to utilize this protein effectively. A reduction in the level or the particle size of the fiber can thus be expected to improve protein utilization.

In present studies, shorts and WPC (as a source of low-fiber shorts) were obtained from two different mills. This did not appear to influence the expected pattern of amino acids between them or the magnitude of their differences. In our samples as also where WPC was prepared from the same shorts (4), practically all the essential amino acids including lysine, the most limiting one, were present in somewhat higher amounts in shorts than in WPC.

The high PER values obtained with shorts point to its nutritional superiority over whole-wheat protein. Still, the desirability of lowering the fiber content is apparent from the results in Table III, whether PER, nitrogen retention, or protein digestibility is considered. Despite a somewhat lower lysine intake, WPC-fed rats showed a more efficient utilization of protein than shorts-fed rats. Though protein digestibility did not improve after the shorts were ground, as has also been reported by Hutchinson and Martin recently (12), growth and nitrogen retention in rats did improve somewhat. Probably grinding shorts several times and to a higher fineness would have ruptured enough aleurone cells to improve protein availability sizably, as has been shown by Saunders et al. (3) in studies with chicks.

The changes in level of plasma-free amino acids can be used to compare the quality of ingested proteins only with caution, since a number of factors, dietary and physiological, seem to affect these changes. However, as pointed out by McLaughlan (13), these changes can serve a very useful index in studying the effect of processing food. At 90 min. postprandial, amino acids from the limited amount

TABLE III. RAT FEEDING EXPERIMENTS

Diet	Performance Data[a]				Nitrogen Retention[a]				Protein Digestibility[b]		
	Food intake g./day	Lysine intake g.	Weight gain g./day	PER[c]	N intake g.	Carcass N g.	N retained[d] %	Relative retention[e] %	Prot. intake g.	Prot. voided g.	Digestibility %
Coarse shorts	12.39 ±0.15	0.88	3.56 ±0.05	2.89 ±0.04	3.66	2.44	36.25 ±0.33	100.0	4.72	1.33	71.8 (70.3–73.4)
Ground shorts	12.04 ±0.12	0.88	3.61 ±0.08	2.95 ±0.05	3.66	2.56	39.57 ±0.64	109.2	4.81	1.40	70.9 (70.0–72.0)
WPC	12.12 ±0.12	0.83	4.05 ±0.03	3.37 ±0.03	3.62	2.63	42.00 ±0.58	115.9	4.78	0.80	83.3 (82.6–83.8)

[a]Mean values for 6 to 7 rats/diet, ± standard error where shown.

[b]Mean values for three rats/diet; range of digestibility in parentheses.

[c]Grams gain/g. protein consumed.

[d]Increase in carcass nitrogen over mean carcass nitrogen of rats sacrificed at start of the experiment (1.11 g.); expressed as % of nitrogen intake.

[e]Ratio of nitrogen retention relative to coarse shorts diet, expressed as %.

TABLE IV. CHANGES IN PLASMA-FREE ESSENTIAL AMINO ACIDS (μmole./100 ml.)[a]

Amino Acid	Diets			Amino Acids, % of Diet		Amino Acid[b] Requirements of Growing Rats, % of Diet
	Shorts		WPC			
	Coarse	Ground		Shorts	WPC	
Lys	+9.21	−3.48	−0.60	0.39	0.37	0.90
His	+5.29	+1.09	+2.69	0.23	0.21	0.25
Arg	+15.28	+21.21	+5.51	0.65	0.53	0.41
Trp	+13.41	+29.52	+8.05	0.18	0.12	0.15
Thr	+6.72	+5.35	+4.80	0.29	0.26	0.50
Val	+8.61	+15.77	+13.05	0.48	0.43	0.55
Met	+3.69	+3.39	+1.41	0.12[c]	0.12[c]	0.50
Ile	+2.72	+2.91	+1.14	0.34	0.31	0.55
Leu	+3.61	+8.19	+0.57	0.59	0.54	0.70
Phe	+7.02	+3.26	+0.63	0.36[d]	0.35[d]	0.70

[a]Values represent the increase (+) or decrease (−) in plasma-free amino acids in response to test diets 90 min. after feeding.

[b]Reference 8.

[c]Cystine: 0.15 (shorts); 0.13 (WPC).

[d]Tyrosine: 0.23 (shorts); 0.20 (WPC).

(0.4 g.) of ingested protein were absorbed into and disappeared from circulation at a comparatively faster rate when WPC or ground shorts were fed to the rats as compared to coarse shorts (Table IV). Lysine as the most limiting amino acid in shorts disappeared from the circulation at the fastest rate. The over-all change in the level of plasma-free amino acids tended to conform to the capacity of the ingested protein to meet the amino acid requirements of growing rats more closely on WPC and ground shorts than on coarse shorts. The data seem to suggest that the level of fiber, as compared to its particle size, has a more pronounced effect on the availability of protein from wheat shorts.

Acknowledgments

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