EXTENSIVE ANALYSES OF FLOURS AND MILLFEEDS MADE FROM NINE DIFFERENT WHEAT MIXES

II. Amino Acids, Minerals, Vitamins, and Gross Energy[1]

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ABSTRACT

Wheat, bran, shorts, red dog, germ, and flour from mixes of five hard red winter, two hard red spring, one white, and one soft red winter wheat were analyzed for 17 amino acids, 9 vitamins and related compounds, 15 minerals, and gross energy content. The amino acids, determined by ion-exchange chromatography, were lysine, histidine, arginine, aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, cystine, valine, methionine, isoleucine, leucine, tyrosine, and phenylalanine. Vitamins and related materials determined were niacin, pantothenic acid, folic acid, thiamine, riboflavin, pyridoxine, alpha-tocopherol, betaine, and choline. Levels of these minerals were determined: Ca, P, K, Na, Mg, Zn, Fe, Mn, Cu, Se, B, Sr, Al, Ba and Co. As is well known, millfeeds contained higher levels of vitamins, minerals, and amino acids than flour milled from the various wheats used.

Wheat and its products are used extensively in diets of humans and farm animals in the U. S. The nutritional attributes of wheat, flour, and by-products have been studied extensively, and Jones and Ziegler (1), National Research Council (2), and Kent (3) have furnished reviews.

Wheat, flour, and millfeeds contain many essential nutrients for proper nutrition of man and animals. Wheat is composed of carbohydrates (mainly starch), proteins, minerals, and vitamins. It is regarded mainly as an energy source. Its value, however, as a source of protein, vitamins, and minerals often is overlooked—at least partially so, to judge from the way various millfeeds are defined in analyses used to market them.

For this study, data were collected on nutritionally important constituents of wheat, flour, and millfeeds from samples of hard red winter, hard red spring, soft red winter, and white wheat obtained from a defined milling operation. Nutritional constituents determined in wheat, flour, bran, germ, red dog, and shorts were vitamins, minerals, gross energy, protein, and amino acids.

Materials and Methods

Samples. Samples used are described by Farrell *et al* (4).

Protein, Moisture, and Amino Acids. Protein and moisture were determined by AACC Methods 44-15 and 46-11 (5), respectively. Amino acids were

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determined by procedures of Waggle *et al* (6). Samples were hydrolyzed in excess 6*N* HCl for 22 hr., and 15 amino acids and ammonia were determined with a Beckman 120B amino acid analyzer. Methionine and cystine were determined by following the procedure outlined by Moore (7), with a 24-hr. oxidation period, and hydrolyzed by procedure previously described for 18-hr. No corrections were made for possible destruction of labile amino acids.

Vitamins and Related Compounds. The following procedures were used to determine quantities of the indicated vitamins[3]: thiamine, AACC method 86-80; riboflavin, AACC method 86-70; pyridoxine, AACC method 86-31; niacin, AACC method 86-51; pantothenic acid, Neilands and Strong (8); folic acid, AOAC method (9) 39.059-39.062; alpha-tocopherol, Bro-Rasmussen and Hjarde (10); choline, AACC method 86-45; and betaine, Walker and Erlandsen (11).

Gross Energy. Gross energy was determined by the Parr bomb calorimetry method.

Minerals. The following procedures were used to determine mineral contents of the various samples (see footnote 3): Se, Gutenmann and Lisk (12); Co, AOAC method 22.074-22.076; and Ca, P, K, Na, Mg, Al, Ba, Fe, Sr, B, Cu, Zn, and Mn by spectrometer elemental analysis, with a computer-programmed emission spectrometer at the Wisconsin Alumni Research Foundation.

Results and Discussion

Amino Acids. Amino acid compositions of the wheat, bran, germ, shorts, red dog, and flour are shown in Tables I, II, III, IV, V, and VI, respectively. Essential amino acids were highest in the germ; next highest in the shorts. In general, bran and red dog contained approximately equal amounts of essential amino acids, and flour contained the least. The milling operation concentrates essential amino acids in mill feeds; hence, on the basis of the amino acid content, the mill products have higher nutritional value than the flour or wheat from which they were milled.

Minerals. Mineral compositions of wheat, bran, germ, shorts, red dog, and flour are shown, respectively, in Tables VII, VIII, IX, X, XI, and XII. In general, bran contains the highest percentages of Ca, P, K, Na, and Mg, and flour contains the lowest percentages of those minerals. The germ also contains relatively high amounts of minerals compared with wheat and flour. Shorts and red dog have intermediate amounts of those nutritionally important minerals. However, wheat and its products are relatively low in amounts of Ca and high in amounts of P. Bran, germ, and shorts contain generally higher concentrations of the nutritionally important trace elements Zn, Mn, Cu, Co, Fe, and possibly Se than do other mill streams, except that Co is evenly distributed in all wheat products.

[3] Choline, thiamine, riboflavin, pyridoxine, and cobalt were determined at Doty Labs., Kansas City, Mo.; and niacin, pantothenic acid, folic acid, alpha-tocopherol, betaine, Se, Ca, P, K, Na, Mg, Al, Ba, Fe, Sr, B, Cu, Zn, and Mn were determined at the Wisconsin Alumni Research Foundation, Madison, Wis.

TABLE I
AMINO ACID COMPOSITION OF WHEAT SAMPLES[a]

	HRW					HRS		White	SRW
	9001	9002	9008	9007	9010	9009	9003	9005	9006
	%	%	%	%	%	%	%	%	%
Protein	10.5	13.1	11.7	11.4	11.8	10.2	13.5	9.9	12.0
Amino acids									
Lysine	0.29	0.35	0.34	0.34	0.35	0.28	0.34	0.32	0.35
Histidine	0.23	0.30	0.30	0.29	0.30	0.24	0.27	0.26	0.31
Arginine	0.49	0.60	0.61	0.62	0.63	0.50	0.54	0.55	0.63
Aspartic acid	0.56	0.63	0.67	0.66	0.65	0.55	0.69	0.57	0.65
Threonine	0.34	0.40	0.35	0.35	0.36	0.33	0.40	0.32	0.38
Serine	0.59	0.69	0.54	0.54	0.57	0.53	0.69	0.52	0.63
Glutamic acid	3.58	4.46	4.16	3.93	3.85	3.72	4.82	3.45	4.27
Proline	1.11	1.54	1.36	1.17	1.28	1.15	1.55	1.06	1.36
Glycine	0.44	0.56	0.56	0.52	0.55	0.46	0.59	0.47	0.53
Alanine	0.39	0.48	0.48	0.43	0.47	0.40	0.50	0.40	0.48
Cystine	0.30	0.38	0.32	0.30	0.33	0.31	0.34	0.29	0.35
Valine	0.41	0.56	0.57	0.59	0.59	0.50	0.56	0.48	0.56
Methionine	0.19	0.24	0.19	0.17	0.20	0.18	0.22	0.16	0.21
Isoleucine	0.34	0.46	0.50	0.47	0.48	0.38	0.49	0.38	0.44
Leucine	0.73	0.94	0.89	0.83	0.86	0.74	0.97	0.74	0.88
Tyrosine	0.34	0.43	0.39	0.38	0.38	0.33	0.42	0.32	0.38
Phenylalanine	0.50	0.67	0.61	0.58	0.60	0.51	0.67	0.49	0.62

[a]Hard red winter, hard red spring, white, and soft red winter wheat as described by Farrell et al. (4). All values reported on 14% moisture basis.

TABLE II
AMINO ACID COMPOSITION OF BRAN[a]

	HRW					HRS		White	SRW
	9001	9002	9008	9007	9010	9009	9003	9005	9006
	%	%	%	%	%	%	%	%	%
Protein	12.9	14.5	13.8	14.1	13.7	11.8	14.3	13.6	13.9
Amino acids									
Lysine	0.56	0.61	0.58	0.61	0.59	0.59	0.60	0.56	0.58
Histidine	0.40	0.50	0.43	0.43	0.41	0.41	0.45	0.40	0.39
Arginine	1.06	1.07	1.09	1.11	1.06	1.02	1.12	1.01	1.06
Aspartic acid	1.10	1.10	1.14	1.20	1.09	1.05	1.14	1.12	1.11
Threonine	0.49	0.51	0.47	0.51	0.36	0.48	0.52	0.49	0.53
Serine	0.66	0.69	0.65	0.68	0.57	0.59	0.69	0.67	0.76
Glutamic acid	2.45	3.16	2.80	2.99	2.64	2.16	3.05	2.81	3.21
Proline	0.74	0.95	0.85	0.91	0.85	0.70	0.91	0.86	1.00
Glycine	0.85	0.87	0.91	0.90	0.87	0.82	0.94	0.89	0.89
Alanine	0.74	0.74	0.76	0.76	0.77	0.70	0.79	0.73	0.80
Cystine	0.33	0.36	0.32	0.36	0.39	0.33	0.38	0.40	0.42
Valine	0.61	0.54	0.76	0.72	0.72	0.70	0.79	0.64	0.68
Methionine	0.20	0.21	0.20	0.20	0.24	0.24	0.22	0.26	0.23
Isoleucine	0.41	0.48	0.50	0.49	0.49	0.39	0.47	0.42	0.46
Leucine	0.85	0.95	0.93	0.94	0.89	0.80	0.95	0.87	0.96
Tyrosine	0.43	0.45	0.43	0.45	0.39	0.38	0.44	0.43	0.47
Phenylalanine	0.54	0.60	0.58	0.59	0.56	0.51	0.60	0.55	0.62

[a]Hard red winter, hard red spring, white, and soft red winter wheat as described by Farrell et al. (4). All values reported on 14% moisture basis.

TABLE III
AMINO ACID COMPOSITION OF GERM[a]

	HRW					HRS		White	SRW
	9001	9002	9008	9007	9010	9009	9003	9005	9006
	%	%	%	%	%	%	%	%	%
Protein	21.9	22.0	22.1	22.6	22.3	25.6	25.0	22.8	21.4
Amino acids									
Lysine	1.44	1.30	1.33	1.38	1.38	1.60	1.64	1.52	1.77
Histidine	0.61	0.64	0.60	0.61	0.59	0.82	0.71	0.62	0.72
Arginine	1.85	1.77	1.80	1.89	1.88	1.93	2.09	1.87	1.78
Aspartic acid	2.05	1.92	2.00	2.14	2.25	2.20	2.18	2.25	1.92
Threonine	0.95	0.89	0.91	0.94	1.05	1.09	1.02	0.96	0.90
Serine	1.07	1.06	1.08	1.12	1.28	1.16	1.05	1.07	1.05
Glutamic acid	3.65	4.21	4.10	4.06	4.59	3.91	4.01	3.71	3.91
Proline	1.13	1.34	1.31	1.26	1.52	1.24	1.16	1.13	1.15
Glycine	1.38	1.32	1.41	1.36	1.57	1.58	1.51	1.42	1.37
Alanine	1.46	1.34	1.52	1.35	1.71	1.65	1.50	1.50	1.43
Cystine	0.43	0.45	0.61	0.44	0.46	0.45	0.49	0.47	0.46
Valine	1.13	1.11	1.15	1.12	1.06	1.20	1.37	1.18	1.01
Methionine	0.39	0.39	0.58	0.42	0.44	0.46	0.49	0.46	0.40
Isoleucine	0.77	0.77	0.80	0.77	0.90	0.86	0.94	0.80	0.79
Leucine	1.52	1.50	1.57	1.52	1.75	1.67	1.69	1.54	1.48
Tyrosine	0.69	0.65	0.69	0.68	0.78	0.78	0.77	0.68	0.67
Phenylalanine	0.91	0.90	0.99	0.91	1.01	0.98	0.98	0.90	0.86

[a]Hard red winter, hard red spring, white, and soft red winter wheat as described by Farrell et al. (4). All values reported on 14% moisture basis.

TABLE IV
AMINO ACID COMPOSITION OF SHORTS[a]

	HRW					HRS		White	SRW
	9001	9002	9008	9007	9010	9009	9003	9005	9006
	%	%	%	%	%	%	%	%	%
Protein	15.2	16.7	16.9	15.8	16.2	15.7	15.7	13.8	15.6
Amino acids									
Lysine	0.86	0.85	0.86	0.78	0.85	0.85	0.74	0.68	0.84
Histidine	0.44	0.50	0.47	0.43	0.49	0.43	0.43	0.37	0.46
Arginine	1.32	1.26	1.32	1.20	1.30	1.21	1.13	1.02	1.21
Aspartic acid	1.36	1.35	1.43	1.29	1.37	1.28	1.25	1.18	1.28
Threonine	0.62	0.63	0.63	0.56	0.61	0.61	0.59	0.54	0.60
Serine	0.81	0.77	0.78	0.71	0.76	0.77	0.75	0.69	0.78
Glutamic acid	2.94	3.33	3.18	3.11	3.10	2.84	3.29	2.75	3.13
Proline	0.92	1.03	0.97	0.97	0.97	0.92	1.00	0.89	1.00
Glycine	0.98	0.98	1.04	0.90	1.02	0.94	0.91	0.83	0.94
Alanine	0.99	0.93	1.02	0.88	0.98	0.94	0.88	0.81	0.91
Cystine	0.36	0.39	0.41	0.36	0.38	0.38	0.31	0.36	0.42
Valine	0.79	0.83	0.92	0.87	0.95	0.75	0.79	0.63	0.80
Methionine	0.27	0.28	0.30	0.26	0.28	0.28	0.29	0.23	0.28
Isoleucine	0.51	0.60	0.63	0.55	0.62	0.51	0.54	0.46	0.55
Leucine	1.08	1.12	1.16	1.04	1.12	1.04	1.05	0.93	1.09
Tyrosine	0.48	0.51	0.51	0.47	0.50	0.47	0.50	0.43	0.51
Phenylalanine	0.65	0.70	0.72	0.67	0.69	0.61	0.66	0.56	0.68

[a]Hard red winter, hard red spring, white, and soft red winter wheat as described by Farrell et al. (4). All values reported on 14% moisture basis.

TABLE V
AMINO ACID COMPOSITION OF RED DOG[a]

	HRW					HRS		White	SRW
	9001	9002	9008	9007	9010	9009	9003	9005	9006
	%	%	%	%	%	%	%	%	%
Protein	12.6	14.1	13.2	13.7	13.6	13.7	14.8	12.6	14.9
Amino acids									
Lysine	0.53	0.53	0.45	0.56	0.54	0.65	0.60	0.60	0.55
Histidine	0.34	0.36	0.32	0.38	0.37	0.39	0.42	0.35	0.41
Arginine	0.89	0.90	0.77	0.97	0.94	1.07	1.01	0.96	0.92
Aspartic acid	0.89	0.87	0.75	0.96	0.94	1.03	1.02	1.01	0.94
Threonine	0.45	0.46	0.42	0.46	0.48	0.56	0.53	0.49	0.52
Serine	0.63	0.69	0.66	0.64	0.74	0.75	0.78	0.67	0.80
Glutamic acid	3.36	3.95	4.15	3.70	4.14	3.73	4.19	3.13	4.80
Proline	0.95	1.26	1.31	1.05	1.25	1.11	1.26	0.96	1.49
Glycine	0.64	0.67	0.60	0.72	0.73	0.80	0.81	0.71	0.73
Alanine	0.63	0.62	0.57	0.66	0.71	0.77	0.77	0.71	0.69
Cystine	0.33	0.35	0.36	0.35	0.37	0.37	0.37	0.39	0.43
Valine	0.63	0.70	0.61	0.71	0.65	0.71	0.74	0.64	0.78
Methionine	0.22	0.24	0.24	0.24	0.25	0.27	0.26	0.24	0.25
Isoleucine	0.44	0.52	0.46	0.53	0.49	0.49	0.54	0.44	0.60
Leucine	0.89	0.99	0.97	0.99	1.00	1.01	1.07	0.91	1.13
Tyrosine	0.39	0.44	0.41	0.43	0.45	0.45	0.48	0.40	0.51
Phenylalanine	0.54	0.66	0.63	0.63	0.66	0.65	0.70	0.56	0.74

[a]Hard red winter, hard red spring, white, and soft red winter wheat as described by Farrell et al. (4). All values reported on 14% moisture basis.

TABLE VI
AMINO ACID COMPOSITION OF FLOUR[a]

	HRW					HRS		White	SRW
	9001	9002	9008	9007	9010	9009	9003	9005	9006
	%	%	%	%	%	%	%	%	%
Protein	9.7	12.6	10.8	10.4	10.8	10.4	13.0	8.3	10.8
Amino acids									
Lysine	0.21	0.24	0.24	0.22	0.22	0.22	0.24	0.21	0.23
Histidine	0.21	0.26	0.25	0.23	0.24	0.22	0.25	0.20	0.26
Arginine	0.37	0.48	0.44	0.41	0.40	0.40	0.43	0.36	0.43
Aspartic acid	0.50	0.52	0.47	0.46	0.47	0.43	0.55	0.41	0.48
Threonine	0.29	0.36	0.30	0.30	0.30	0.30	0.37	0.28	0.33
Serine	0.54	0.69	0.54	0.54	0.55	0.53	0.71	0.50	0.60
Glutamic acid	3.25	5.51	4.77	4.32	4.70	3.67	4.64	3.38	4.30
Proline	1.32	1.63	1.35	1.40	1.35	1.34	1.74	1.08	1.44
Glycine	0.38	0.49	0.42	0.42	0.42	0.40	0.53	0.36	0.43
Alanine	0.76	0.40	0.35	0.36	0.35	0.34	0.41	0.32	0.38
Cystine	0.29	0.33	0.29	0.29	0.26	0.32	0.36	0.23	0.36
Valine	0.43	0.54	0.54	0.48	0.53	0.45	0.49	0.39	0.48
Methionine	0.18	0.20	0.17	0.17	0.16	0.20	0.22	0.15	0.21
Isoleucine	0.36	0.50	0.47	0.42	0.46	0.39	0.49	0.32	0.42
Leucine	1.00	1.00	0.84	0.79	0.82	0.77	1.00	0.67	0.84
Tyrosine	0.32	0.43	0.30	0.33	0.28	0.30	0.40	0.29	0.39
Phenylalanine	0.47	0.72	0.59	0.56	0.59	0.55	0.72	0.46	0.58

[a]Hard red winter, hard red spring, white, and soft red winter wheat as described by Farrell et al. (4). All values reported on 14% moisture basis.

TABLE VII

MINERAL COMPOSITION OF WHEAT[a]

	HRW					HRS		White	SRW
	9001	9002	9008	9007	9010	9009	9003	9005	9006
	%	%	%	%	%	%	%	%	%
Ca	0.033	0.041	0.041	0.038	0.043	0.024	0.024	0.024	0.024
P	0.36	0.43	0.35	0.32	0.38	0.36	0.34	0.28	0.41
K	0.37	0.41	0.34	0.43	0.43	0.32	0.32	0.37	0.41
Na	0.011	0.008	<0.005	0.016	0.010	<0.005	<0.005	<0.005	0.010
Mg	0.11	0.11	0.10	0.09	0.11	0.12	0.10	0.09	0.10
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
Zn	63	37	40	44	35	25	49	21	41
Fe	25	31	25	26	26	22	18	30	22
Mn	24	31	24	25	33	34	37	24	28
Cu	1.8	4.2	4.3	4.4	4.2	4.2	6.2	4.2	4.2
Se	0.12	0.30	0.25	0.22	0.50	0.71	0.30	0.04	0.04
B	1.1	1.8	1.1	1.2	1.2	2.2	1.0	1.8	2.2
Sr	0.86	0.86	0.86	<0.50	<0.50	0.86	0.52	0.48	0.48
Al	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Ba	7.2	5.7	7.1	6.9	6.5	3.5	2.4	3.5	6.2
Co	0.12	0.09	0.07	0.17	0.20	0.11	0.13	0.13	0.10

[a]Hard red winter, hard red spring, white, and soft red winter wheat as described by Farrell et al (4). All values reported on 14% moisture basis.

TABLE VIII

MINERAL COMPOSITION OF BRAN[a]

	HRW					HRS		White	SRW
	9001	9002	9008	9007	9010	9009	9003	9005	9006
	%	%	%	%	%	%	%	%	%
Ca	0.072	0.120	0.130	0.082	0.083	0.071	0.057	0.081	0.082
P	1.4	1.2	1.4	1.3	1.5	1.3	1.2	0.9	1.5
K	1.6	1.5	1.2	1.5	1.9	1.2	1.6	1.3	1.6
Na	0.020	0.015	0.005	0.031	0.041	0.018	0.020	0.005	0.030
Mg	0.48	0.53	0.48	0.48	0.51	0.64	0.48	0.39	0.55
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
Zn	134	108	104	141	113	86	131	56	124
Fe	77	85	88	103	93	81	74	95	76
Mn	72	108	96	96	118	138	144	86	91
Cu	10.6	12.5	8.4	14.0	16.0	12.4	17.1	8.4	10.5
Se	0.17	0.62	0.21	0.29	0.75	0.19	0.51	0.10	0.10
B	5.8	4.8	2.2	4.3	6.3	4.3	5.2	3.2	4.3
Sr	4.3	5.3	6.2	4.3	1.8	<1.0	2.2	1.7	1.7
Al	<5.0	7.5	<5.0	10.0	5.0	<5.0	<5.0	<5.0	<5.0
Ba	21.1	17.3	26.9	26.0	24.0	13.3	9.0	13.3	23.0
Co	0.11	0.11	0.12	0.08	0.10	0.12	0.10	0.12	0.08

[a]Hard red winter, hard red spring, white, and soft red winter wheat as described by Farrell et al. (4). All values reported on 14% moisture basis.

TABLE IX
MINERAL COMPOSITION OF GERM[a]

	HRW					HRS		White	SWR
	9001	9002	9008	9007	9010	9009	9003	9005	9006
	%	%	%	%	%	%	%	%	%
Ca	0.041	0.062	0.071	0.059	0.058	0.036	0.036	0.041	0.041
P	0.91	0.96	0.86	0.88	0.91	0.86	0.86	0.77	0.77
K	0.91	0.96	0.86	1.3	1.2	0.91	0.90	0.96	0.86
Na	0.020	0.020	0.013	0.037	0.029	0.015	0.020	.0.015	0.020
Mg	0.22	0.25	0.25	0.25	0.24	0.23	0.22	0.21	0.20
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m-*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
Zn	144	118	107	<100	<100	110	138	101	125
Fe	48	52	39	47	46	41	41	58	43
Mn	101	129	95	108	112	129	127	147	101
Cu	8.6	8.6	7.6	11.8	10.6	8.6	8.6	7.2	7.2
Se	0.27	0.29	0.23	0.34	0.77	0.60	0.32	0.02	0.01
B	5.3	5.3	3.0	6.4	6.2	5.8	4.3	3.8	4.1
Sr	2.2	2.9	3.6	2.3	0.86	0.5	2.2	3.2	0.5
Al	<5.0	<5.0	<5.0	7.4	<5.0	<5.0	<5.0	<5.0	<5.0
Ba	8.6	7.7	9.0	9.8	8.6	4.5	3.4	6.7	7.7
Co	0.09	0.12	0.09	0.10	0.11	0.14	0.14	0.09	0.14

[a]Hard red winter, hard red spring, white, and soft red winter wheat as described by Farrell et al. (4). All values reported on 14% moisture basis.

TABLE X
MINERAL COMPOSITION OF SHORTS[a]

	HRW					HRS		White	SRW
	9001	9002	9008	9007	9010	9009	9003	9005	9006
	%	%	%	%	%	%	%	%	%
Ca	0.072	0.087	0.096	0.085	0.083	0.057	0.057	0.072	0.072
P	0.77	0.92	0.82	0.75	0.88	0.81	0.78	0.54	0.82
K	0.84	0.97	0.82	1.0	1.1	0.81	0.95	0.89	0.91
Na	0.020	0.016	0.012	0.021	0.021	0.013	0.020	<0.005	0.020
Mg	0.22	0.29	0.25	0.25	0.28	0.29	0.24	0.20	0.24
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
Zn	149	114	103	100	100	80	131	62	115
Fe	38	66	58	75	66	55	68	79	58
Mn	91	126	101	107	122	127	142	115	110
Cu	11.5	13.6	8.6	11.0	14.0	11.4	13.3	7.7	13.4
Se	0.34	0.41	0.35	0.31	0.70	0.75	0.52	0.03	0.04
B	3.8	4.6	2.2	2.3	4.2	4.1	4.1	3.1	4.8
Sr	4.3	4.1	4.0	3.5	2.4	0.9	2.2	2.9	0.9
Al	<5.0	7.3	<5.0	7.5	7.4	<5.0	<5.0	<5.0	<5.0
Ba	13.4	11.6	15.4	16.0	14.0	9.0	8.6	10.6	14.4
Co	0.14	0.09	0.09	0.09	0.10	0.09	0.12	0.11	0.09

[a]Hard red winter, hard red spring, white, and soft red winter wheat as described by Farrell et al. (4). All values reported on 14% moisture basis.

TABLE XI
MINERAL COMPOSITION OF RED DOG[a]

	HRW					HRS		White	SRW
	9001	9002	9008	9007	9010	9009	9003	9005	9006
	%	%	%	%	%	%	%	%	%
Ca	0.041	0.042	0.042	0.059	0.042	0.041	0.041	0.040	0.041
P	0.46	0.47	0.37	0.54	0.54	0.62	0.52	0.36	0.36
K	0.41	0.42	0.35	0.64	0.54	0.57	0.62	0.52	0.34
Na	0.009	<0.005	0.009	0.021	0.016	0.011	0.015	0.008	0.011
Mg	0.12	0.12	0.09	0.14	0.13	0.20	0.15	0.11	0.08
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
Zn	99	58	45	74	58	19	100	49	62
Fe	39	35	28	57	39	46	41	56	28
Mn	53	58	32	54	52	71	71	69	43
Cu	5.3	5.8	4.1	8.8	7.4	8.6	8.6	6.1	5.2
Se	0.13	0.43	0.23	0.24	0.60	0.17	0.41	0.30	0.14
B	1.2	1.2	1.2	2.2	2.3	3.8	2.2	2.2	2.2
Sr	0.86	0.87	0.87	0.88	0.88	0.48	0.86	0.85	<0.50
Al	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Ba	6.7	3.5	5.3	7.8	5.4	4.5	3.5	6.1	3.4
Co	0.07	0.11	0.12	0.18	0.17	0.11	0.10	0.09	0.11

[a]Hard red winter, hard red spring, white, and soft red winter wheat as described by Farrell et al. (4). All values reported on 14% moisture basis.

TABLE XII
MINERAL COMPOSITION OF THE FLOUR[a]

	HRW			HRS		White	SRW
	9001	9002	9008	9009	9003	9005	9006
	%	%	%	%	%	%	%
Ca	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
P	0.076	0.100	0.078	0.097	0.100	0.077	0.078
K	0.130	0.130	0.087	0.073	0.086	0.130	0.087
Na	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Mg	0.013	0.014	0.014	0.019	0.013	0.021	0.012
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
Zn	10.5	5.8	3.9	3.9	7.7	3.4	7.3
Fe	3.5	3.6	6.3	3.6	3.6	9.1	3.7
Mn	2.1	3.5	2.1	3.5	3.5	3.5	3.1
Cu	0.62	0.63	0.63	0.63	0.62	0.62	0.63
Se	0.08	0.16	0.08	0.45	0.13	0.02	0.01
B	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Sr	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Al	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Ba	2.7	1.0	1.0	<1.0	<1.0	<1.0	<1.0
Co	0.06	0.07	0.06	0.06	0.06	0.05	0.07

[a]Hard red winter, hard red spring, white, and soft red winter wheat as described by Farrell et al. (4). All values reported on 14% moisture basis.

TABLE XIII

VITAMIN COMPOSITION OF WHEAT[a]

	HRW					HRS		White	SRW
	9001	9002	9008	9007	9010	9009	9003	9005	9006
	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.
Niacin	51.4	53.7	56.0	49.5	56.9	49.7	62.5	46.6	48.4
Pantothenic acid	10.3	10.4	10.1	7.19	8.72	8.3	10.1	8.4	8.6
Folic acid	0.282	0.378	0.407	0.348	0.426	0.403	0.448	0.372	0.410
Thiamine	3.47	3.96	3.87	3.78	3.34	4.16	4.36	4.11	4.11
Riboflavin	1.52	1.89	1.56	1.52	1.52	1.45	1.56	1.32	1.54
Pyridoxine	1.72	2.53	2.51	3.72	0.92	2.02	3.30	2.02	1.69
Alpha-tocopherol	15.6	15.4	15.6	9.7	8.8	15.0	12.8	14.5	15.2
Betaine	337.9	752.4	1,337.6	<220.0	462.0	783.6	1,233.1	1,026.5	1,442.1
Choline	970.2	1,258.4	970.2	1,199.0	866.8	1,152.8	1,258.4	1,139.6	981.2

[a]HRW, HRS, Wh, and SRW wheat as described by Farrell et al. (4). All values reported on 14% moisture basis.

TABLE XIV

VITAMIN COMPOSITION OF BRAN[a]

	HRW					HRS		White	SRW
	9001	9002	9008	9007	9010	9009	9003	9005	9006
	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.
Niacin	314.9	302.4	332.2	249	273	284.1	359.1	275.5	290.0
Pantothenic acid	29.9	33.7	35.5	23.4	29.4	34.6	40.6	34.8	26.6
Folic acid	1.05	1.32	1.09	1.14	1.11	1.14	1.42	0.88	1.12
Thiamine	5.74	6.75	5.52	6.95	5.06	6.62	6.40	5.85	5.90
Riboflavin	5.04	5.76	4.69	4.91	4.95	4.60	4.75	4.33	4.64
Pyridoxine	8.98	8.73	7.30	7.24	9.22	10.69	8.62	7.10	7.04
Alpha-tocopherol	28.4	27.1	27.9	24.0	23.1	24.9	19.8	22.2	19.8
Betaine	3,210.2	2,914.5	6,399.4	5,408	5,089	4,514.4	4,514.4	7,482.2	3,759.4
Choline	1,920.6	2,695.0	2,398.0	1,740.2	2,138.4	1,856.8	2,118.6	2,013.0	2,134.0

[a]HRW, HRS, Wh, and SRW wheat as described by Farrell et al. (4). All values reported on 14% moisture basis.

TABLE XV
VITAMIN COMPOSITION OF GERM[a]

	HRW					HRS		White	SRW
	9001	9002	9008	9007	9010	9009	9003	9005	9006
	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.
Niacin	64.5	85.4	84.8	77.6	84.3	67.4	73.5	71.5	65.2
Pantothenic acid	24.9	26.7	24.4	18.6	18.6	20.7	25.7	17.9	19.2
Folic acid	1.43	1.66	1.51	1.93	1.79	2.96	2.65	2.59	2.04
Thiamine	21.78	22.75	18.72	24.18	21.10	20.90	22.97	24.02	20.15
Riboflavin	5.54	5.50	5.48	5.72	5.98	6.42	5.76	6.25	5.81
Pyridoxine	10.96	13.62	10.41	12.01	19.80	11.40	10.82	9.31	6.62
Alpha-tocopherol	106.9	162.1	136.0	31.0	108.6	148.9	201.7	159.5	136.2
Betaine	4,942.1	4,583.0	6,040.1	3,062	5,408	4,984.3	3,908.3	5,998.1	4,519.7
Choline	3,282.4	2,873.2	2,622.4	3,297.8	3,009.6	3,106.4	3,245.0	2,591.6	2,989.8

[a]HRW, HRS, Wh, and SRW wheat as described by Farrell et al. (4). All values reported on 14% moisture basis.

TABLE XVI
VITAMIN COMPOSITION OF SHORTS[a]

	HRW					HRS		White	SRW
	9001	9002	9008	9007	9010	9009	9003	9005	9006
	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.
Niacin	84.5	108.6	107.5	102.0	117.0	119.7	124.5	113.3	92.0
Pantothenic acid	24.0	27.0	27.0	17.3	20.6	24.4	27.2	23.0	23.3
Folic acid	1.25	1.57	1.42	1.41	1.47	1.97	1.95	1.34	1.72
Thiamine	20.13	19.87	19.78	20.24	19.34	21.85	21.56	17.80	16.35
Riboflavin	4.64	4.86	5.24	4.66	5.06	4.47	5.19	4.03	4.73
Pyridoxine	6.80	9.79	6.03	7.92	7.46	4.69	8.34	6.36	5.92
Alpha-tocopherol	55.4	52.4	82.3	57.6	55.7	5.85	66.9	48.6	55.4
Betaine	3,632.6	4,481.4	5,449.0	4,840	4,398	3,845.6	3,699.3	5,998.1	3,083.5
Choline	2,347.4	1,944.8	2,127.4	1,980.0	2,074.6	2,125.2	1,850.2	1,779.8	2,017.4

[a]HRW, HRS, Wh, and SRW wheat as described by Farrell et al. (4). All values reported on 14% moisture basis.

TABLE XVII
VITAMIN COMPOSITION OF RED DOG[a]

	HRW					HRS		White	SRW
	9001	9002	9008	9007	9010	9009	9003	9005	9006
	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.
Niacin	33.6	32.4	29.5	47.3	44.7	61.3	61.6	46.3	21.9
Pantothenic acid	12.4	12.5	12.3	12.0	11.3	17.2	17.4	12.6	8.95
Folic acid	0.584	0.616	0.406	0.721	0.572	1.15	1.03	1.01	0.560
Thiamine	23.76	21.47	13.93	23.23	21.78	29.81	27.74	28.45	19.03
Riboflavin	2.44	2.24	1.74	2.62	2.22	3.23	3.06	2.64	1.91
Pyridoxine	5.90	5.26	2.13	8.60	3.96	3.52	6.31	4.82	2.66
Alpha-tocopherol	32.3	31.5	28.6	29.3	26.4	37.2	37.2	32.1	26.0
Betaine	3,527.0	3,179.7	4,545.4	2,350	4,204	3,553.0	4,284.5	3,825.8	2,445.3
Choline	1,452.0	1,460.8	1,403.6	1,676.4	1,742.4	1,639.0	1,966.8	1,634.6	1,454.2

[a]HRW, HRS, Wh, and SRW wheat as described by Farrell et al. (4). All values reported on 14% moisture basis.

TABLE XVIII
VITAMIN COMPOSITION OF FLOUR[a]

	HRW			HRS		White	SRW
	9001	9002	9008	9009	9003	9005	9006
	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.
Niacin	9.5	10.0	8.2	9.7	10.7	11.4	8.1
Pantothenic acid	4.99	5.01	5.19	3.30	4.78	3.72	4.29
Folic acid	0.103	0.136	0.120	0.120	0.129	0.119	0.116
Thiamine	0.79	1.47	1.17	1.39	1.28	1.28	1.36
Riboflavin	0.33	0.37	0.37	0.35	0.37	0.33	0.31
Pyridoxine	0.51	1.19	0.42	0.42	1.01	0.73	1.36
Alpha-tocopherol	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2	3.1
Betaine	2,087.8	1,280.4	<220.0	298.8	<220.0	<220.0	219.8
Choline	697.4	787.8	807.4	979.0	840.4	561.0	697.4

[a]HRW, HRS, Wh, and SRW wheat as described by Farrell et al. (4). All values reported on 14% moisture basis.

Vitamins. Tables XIII, XIV, XV, XVI, XVII, and XVIII show results of vitamin determinations of wheat, bran, germ, shorts, red dog, and flour, respectively. Bran contained the most niacin; flour the least. Thiamine, pyridoxine, alpha-tocopherol, betaine, and choline were highest in the germ. Riboflavin was approximately equal in bran, germ, shorts, and red dog. As these and previous data have shown, the millfeeds, especially germ, had higher vitamin contents than the flour. They, therefore, have higher nutritional quality than flour, on the basis of vitamin contents.

TABLE XIX

GROSS ENERGY OF WHEAT, FLOUR, AND MILLFEEDS[a]

	HRW					HRS		White	SRW
	9001	9002	9008	9007	9010	9009	9003	9005	9006
	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.
Wheat	4,407	4,419	4,397	4,438	4,495	4,421	4,433	4,386	4,410
Flour	4,343	4,397	4,461	4,375	4,407	4,404	4,401	4,340	4,388
Germ	5,062	5,088	4,893	4,940	4,987	5,138	5,107	4,879	5,034
Red dog	4,554	4,661	4,513	4,623	4,497	4,840	4,617	4,528	4,625
Shorts	4,953	4,952	4,959	4,919	4,998	4,970	5,032	4,897	5,062
Bran	4,555	4,501	4,568			4,612	4,578	4,539	

[a]HRW, HRS, Wh, and SRW wheat as described by Farrell et al. (4). All values reported on zero moisture basis.

Gross Energy. Gross energy values are shown in Table XIX for wheat, germ, bran, red dog, shorts, and flour. Germ and shorts had highest gross energy values, probably from higher fat concentrations. Bran, flour, red dog, and wheat contained relatively equal gross energy.

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Literature Cited

1. JONES, C. E., and ZIEGLER, E. Principles of milling. *In* Wheat: Chemistry and technology, I. Hlynka, ed.; pp. 111–193. American Association of Cereal Chemists: St. Paul, Minnesota (1964).
2. NATIONAL ACADEMY OF SCIENCES-NATIONAL RESEARCH COUNCIL. Committee on Animal Nutrition and National Committee on Animal Nutrition in Canada 1959, Joint U.S.-Canada Tables of Feed Composition. Publ. 659.
3. KENT, N. L. Technology of cereals with special reference to wheat. Pergamon Press: Oxford, England (1966).
4. FARRELL, E. P., WARD, A. B., MILLER, G. D., and LOVETT, L. A. Extensive analyses of the flours and millfeeds made from nine different wheat mixes. I. Amounts and analyses. Cereal Chem. **44:** 39–47 (1967).
5. AMERICAN ASSOCIATION OF CEREAL CHEMISTS. Cereal laboratory methods (7th ed.). The Association: St. Paul, Minnesota (1962).
6. WAGGLE, D. H., PARRISH, D. B., and DEYOE, C. W. Nutritive value of protein in high and low protein content sorghum grain as measured by rat performance and amino acid assays. J. Nutrition **88:** 370–374 (1966).
7. MOORE, S. On the determination of cystine as cysteic acid. J. Biol. Chem. **238:** 235–237 (1963).

8. NEILANDS, J. B., and STRONG, F. M. The enzymatic liberation of pantothenic acid. Arch. Biochem. **19:** 287–291 (1948).
9. ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. Official methods of analysis (9th ed.). The Association: Washington, D. C. (1960).
10. BRO-RASMUSSEN, F., and HJARDE, W. Determination of alpha-tocopherol by chromatography on secondary magnesium phosphate. Acta Chem. Scand. **11:** 34–43 (1957).
11. WALKER, H. G., and ERLANDSEN, ROBERTA. Rapid method for determination of betaine. Anal. Chem. **23:** 1309 (1951).
12. GUTENMANN, W. H., and LISK, D. J. Determination of selenium in oats by oxygen flask combustion. J. Agr. Food Chem. **9:** 488–489 (1961).