Nutrient Levels in Internationally Milled Wheat Flours

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ABSTRACT

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Ninety-five samples of commercially milled wheat flours, collected in 30 different countries, were analyzed for ash, protein, thiamin, riboflavin, niacin, iron, calcium, magnesium, and zinc content. Information on wheat, milling extraction rates, flour type and its end-use, production quantities, and government regulations was also obtained. A nutrient score, reflecting composition and density of the wheat nutrients in flour, was described and calculated for individual samples. Nutrient levels increased directly with flour ash values, except for calcium and protein, which showed little change. The majority of mills used extraction rates of 72–78%, with 16% of the mills reporting rates over 80%. The total production represented by the tested flours was estimated to be 4.6 million tons. The nutrient score of typical flour (ash 0.6% or below, extraction 72–78%) was 29, about one-third that of optimum wheat. Only 11 samples, from nine different countries, were supplemented with vitamins and minerals (enriched) to varying degrees. Thus, the nutritional quality of a large proportion of flour produced throughout the world is lower than that of wheat as a result of the milling process.

The world's most widely cultivated food plant, wheat, supplies more nutrients (calories, protein, and certain vitamins and minerals) for human nutrition than does any other single source of food. Some of these nutrients are consumed directly; those in animal feeds derived from wheat are consumed indirectly. The quantity of wheat-based nutrients available for direct human consumption in various geographic regions of the world is best determined from the nutrient composition of the wheat flour used in the particular area. Similar data for wheat, although more readily available, are less accurate because they do not reflect nutrient losses from milling and manufacturing. In view of the wide acceptance of modern milling technology even in the developing countries, these losses are not inconsequential.

A survey of the nutrient composition of commercially milled wheat flours produced in the United States and Canada has recently been reported in a series of papers (Keagy et al 1980, Kulp et al 1980, Lorenz et al 1980). The present study extended this type of investigation to internationally milled wheat flours. Its specific objectives were to obtain information on current milling practices and types of flour produced in various countries and to determine the nutrient composition of these flours. Such information could be used to more clearly define the direct nutritional contribution of wheat. In conjunction with public health data and other considerations, it could assist in evaluation of the advisability of an enrichment intervention program.

MATERIALS AND METHODS

Sampling

Samples of commercially milled wheat flour were collected and documented by representatives of the offices of USDA Agricultural Attachés, commercial concerns, and wheat exporting agencies. An effort was made to obtain a worldwide sample collection representing major wheat-consuming areas. The actual locations sampled were determined mainly by opportunity rather than by any sampling plan. Only samples that represented a staple mill product typically produced for, and consumed by, a significant proportion of the local populace were taken.

The flour samples, collected over a six-month period, were stored at 20° F.

Sample Documentation

The following information was requested for each sample: 1) Sampling location and type of operation (mill, bakery, etc); 2) origin and type of wheat milled for the flour sample; 3) milling data: location, mill capacity, amount of wheat used per year, annual production of the sampled flour, extraction rate, flour grade (patent, straight, stuffed straight, etc), and flour treatments applied (enriched, bleached, etc); 4) end-use data: location of use (home or bakery), types of products made from the sampled flour (white pan bread, hearth bread, chemically leavened products, etc), and whether these baked products were typical in the area; 5) government regulations about pricing and enrichment of wheat, flour, and bread.

Assay Procedures

Protein, moisture, and ash contents were determined according to AACC procedures 46-10, 44-16, and 08-01, respectively.

Vitamin contents were determined by semiautomated methods (riboflavin by AACC method 86-73, thiamin by a semiautomated version of AACC method 86-80, and niacin by AACC method 86-52), using a single extract according to the procedure described by Ranum (1977).

Minerals were determined by atomic absorption spectrophotometry (AACC method 40-70) using the dry ashing procedure of extraction.

Nutrient Score

To express the nutrient levels of various flour samples in comparable terms, a nutrient score (S) was devised, defined by the general equation:

$$S = 100 \sum_{i=1}^{i=N} (F_i/D_i) \Big/ \sum_{i=1}^{i=N} (W_i/D_i) \qquad (1)$$

where:

F_i = level of nutrient i in flour.
W_i = level of nutrient i in wheat.
D_i = dietary requirement.
N = number of nutrients included in score.

The general formula for S was modified for calculation of the nutrient score of sampled flours. First, W_i values corresponding to the high range reported for each nutrient by various investigators (Table III) were chosen. Collectively, they represent a wheat of maximum composition, to which, by definition, a nutrient score of 100 was assigned. Such wheat is unlikely to be encountered in actual practice; most wheats or whole wheat flours are expected to have S below 100. For example, ten U.S. wheat samples studied by Lorenz et al (1980) and Keagy et al (1980) showed an S of 82 ± 6. Second, eight nutrients (protein, three vitamins, and four minerals) were included in the nutrient score (N = 8). Third, for D_i values, the U.S. recommended daily allowances (US RDA) were used (U.S. Code of Federal Regulations 1978). With these modifications, the

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TABLE I
Nutrient[a] Levels in Some Internationally Milled Wheat Flours

Mill Flour Production[b] (1,000 MT/yr)	Wheat[2] Source[c]	Type[d]	Extraction/ Patent[e] (%)	Flour Ash (%)	Uses[f]	Protein (%)	Vitamins and Minerals, ppm B_1	B_2	Niacin	Fe	Ca	Zn	Mg	Nutrient Score[g]
Argentina														
76	D	···	76 P	0.44	BYHF	11.2	0.7	0.3	9	10	140	8	160	24
53	D	···	76 S	0.71	BHF	13.1	1.8	0.4	14	17	240	15	340	39
	D	H	72 S	0.58	BF	11.3	1.6	0.5	12	11	160	11	270	32
			···	0.65	BFS	10.6	1.0	0.5	9	13	130	8	180	26
Brazil														
···	···	···		0.47	BFY	13.5	2.0	0.3	10	18	160	11	250	36
22	D/U	···	78 S	0.62	HNF	14.6	3.2	0.5	15	26	180	20	390	50
		···	78 P	0.34	···	12.4	0.8	0.3	7	11	140	10	160	26
Chile														
66	D/U	H/S	78 S	0.58	BFY	10.0	3.1	0.6	17	18	170	10	300	40
49	D/C	H	75 S	0.46	P	9.5	0.6	0.3	13	7	130	7	250	24
Colombia														
17	U/Ar	H	72–75 S	0.60	BH	11.1	2.2	0.3	13	12	190	10	310	34
10	Ar	H	75 S	0.70	BHY	11.2	2.2	0.4	18	14	191	11	500	39
2	D/U	H	78 S	0.67	BHY	10.7	2.4	0.5	16	17	180	10	370	38
14	U	H	76 S	0.66	P	10.4	2.1	0.4	16	13	170	10	360	35
9	U	H	72 S	0.69	S	10.9	1.8	0.4	17	35	190	10	370	42
9	D	···	80 S	0.56	BHF	10.3	2.1	0.4	12	13	180	9	260	32
Ecuador														
66	D/I	H/S	76 S	0.54	N(E)	11.0	13.3	7.4	88	46	210	9	310	126
			S	0.54	N	11.1	2.1	0.6	13	12	190	9	310	34
			SS	1.54	P	12.9	11.1	1.5	26	42	140	35	1,200	115
			S	0.51	B	11.2	1.8	0.5	13	12	200	8	290	32
			S	0.52	S	9.4	2.2	0.4	10	19	170	8	220	32
11	I	H	78 S	0.65	BHF	11.1	2.1	0.4	19	14	200	11	390	38
Germany														
144	D	S	70 ···	0.39	FYS	8.8	0.6	0.2	6	5	140	4	110	17
			80 ···	0.58	BH	11.8	5.9	1.3	31	26	200	16	560	66
Great Britian														
78	U/C	H/S	75 S	0.92	BH(E)	12.2	3.6	0.6	20	21	900	12	350	50
120	···	···	75 S	0.71	BH(E)	10.4	2.7	0.4	17	18	560	8	200	38
Guatemala														
23	U	H	75 S	0.48	FHSY(E)	13.9	6.6	3.9	55	53	550	11	370	88
Hong Kong														
23	U	H	75 S	0.50	BH	13.9	1.3	0.2	14	19	190	9	350	38
23	U	S	75 P	0.45	SY	8.8	1.5	0.1	10	11	220	4	230	25
India														
21	D/I	S	68 S	0.56	FBYP	8.8	1.3	0.4	13	11	160	6	230	26
13	D	S/H	50 S	0.56	FBYP	9.1	1.3	0.6	16	20	170	8	350	33
···	···	···	···	0.58	···	8.4	1.8	0.6	15	27	150	6	320	35
···	···	···	···	1.56	···	10.0	4.0	1.0	44	45	200	19	850	71
···	···	···	···	0.59	···	9.7	1.6	0.5	15	15	180	6	340	32
25	D/I	···	52 S	0.52	B	8.5	1.1	0.4	13	30	180	6	250	31
···	···	···	···	0.49	···	8.3	0.7	0.3	14	10	130	4	200	22
Indonesia														
450	U	H	75 P	0.45	H	12.7	1.1	0.4	12	16	150	9	300	32
	U/A		75 P	0.49	FN	10.5	1.8	0.2	12	13	160	7	330	31
144	U/A	S	72 P	0.42	S	7.1	1.6	0.3	10	8	190	6	190	23
Iran														
21	D/I	···	97 P97	1.41	H	10.7	3.1	1.0	45	39	210	21	930	68
25		···	87 P68–79	0.62	FBS	9.1	2.1	0.6	12	19	210	8	220	33
31		···	87 P84	2.40	H	10.1	3.7	0.9	31	39	310	15	620	60
22		···	87 P82	1.19	H	10.5	5.0	0.9	32	37	230	19	880	69
Italy														
9	D	S	78 S	0.47	B	9.6	1.6	0.4	11	11	150	8	240	28
Japan														
380	U/C	H	72–80 P	0.39	B	12.1	0.7	0.4	12	11	120	7	280	27
	U	S	72–80 P	0.40	SFC	8.0	1.3	0.3	9	6	160	3	220	21
	U/A	S	72–80	0.39	NY	8.1	1.0	0.2	9	7	140	3	170	20
50	D	···	72–80 P	0.26	N	9.5	1.1	0.2	6	5	120	4	100	19
Kenya														
39	D	S	75 S	0.56	FH	10.7	1.5	0.4	14	18	260	12	260	34
	D/U	···	...	0.57	FH	10.6	1.4	0.4	13	16	320	11	240	32
Korea														
236	U	H/S	80 P	0.46	FBN	8.9	0.9	0.2	9	20	180	5	190	25
14	U	H	80 P	0.49	FYN	12.4	0.8	0.3	12	20	130	8	260	30
8	U	S	80 P	0.48	Y	9.1	1.2	0.4	9	10	240	5	190	24

(continued on next page)

TABLE I
Nutrient[a] Levels in Some Internationally Milled Wheat Flours (continued)

Mill Flour Production[b] (1,000 MT/yr)	Wheat[2] Source[c]	Wheat[2] Type[d]	Extraction/ Patent[e] (%)	Flour Ash (%)	Flour Uses[f]	Protein (%)	Vitamins and Minerals, ppm B_1	B_2	Niacin	Fe	Ca	Zn	Mg	Nutrient Score[g]
Malaysia														
137	A	···	72 S	0.47	FYN	10.8	1.3	0.4	9	9	200	5	250	26
180	U/A	···	72 S	0.51	B	13.1	1.3	0.4	13	15	190	9	350	34
Mexico														
126	D/I	···	79 S	0.55	H	10.2	2.0	0.4	15	12	180	11	350	34
47	D/I	···	76 P	0.49	H	10.0	1.2	0.3	14	10	170	9	270	28
27	D/I	···	76 P	0.53	B	10.5	1.9	0.4	16	15	170	10	310	34
Nigeria														
120	U	H	75 S	0.53	B(E)	11.4	2.7	1.1	22	28	160	9	280	44
Peru														
81	A/Ar	H	82 P	0.91	PS	12.0	3.4	0.7	24	21	160	17	590	52
79	A/Ar	H	82 S	0.89	PH	11.6	2.5	0.6	23	19	140	18	600	54
148	A/Ar	S	82 P	0.83	PFH	12.0	3.4	0.7	19	17	150	18	500	49
···	···	···	···	1.09	···	12.2	4.2	0.9	25	24	140	23	650	67
107	U/A/Ar	H	83 P	0.76	FBYSP	11.6	2.4	0.6	19	17	150	14	450	42
			S	1.04	FBYSP	12.2	3.3	0.8	26	25	160	20	650	56
Philippines														
145	U	H	80 S	0.57	BHP(E)	13.4	5.6	2.6	42	42	140	11	380	73
Puerto Rico (U.S.)														
32	U	H	75 S	0.53	B(E)	13.2	7.8	4.9	68	42	170	10	240	93
Sicily														
11	D	H	75 S	0.70	H	8.8	1.2	0.4	16	10	190	9	320	29
2	F	S	75 P	0.44	BP	9.3	0.8	0.3	10	11	160	4	120	22
3	F	H	76 S	0.81	B	11.0	1.6	0.6	27	14	190	11	350	38
Singapore														
30	A	S	74 S	0.48	BSNF	10.3	1.4	0.2	10	9	150	7	220	26
	A/U	H	73 S	0.48	B	12.8	1.2	0.2	13	13	150	9	310	30
	A	S	74 S	0.47	BN	9.9	1.5	0.2	10	9	160	7	210	26
South Africa														
97	D	···	70	0.44	CS	10.4	0.7	0.3	10	17	170	5	180	25
			80	0.67	B	11.0	2.3	0.5	10	32	200	13	440	44
			90	1.02	BH	11.2	2.8	0.7	29	29	210	18	660	55
122	D	···	70	0.47	CS	9.5	0.9	0.2	11	9	150	6	240	24
			80	0.68	B	10.7	2.9	0.5	16	20	180	13	440	42
			90	1.28	BP	10.6	2.7	0.8	35	33	210	22	840	60
34	D	···	70	0.49	CS	9.1	0.6	0.4	12	24	110	3	200	26
			80	0.83	BH	9.7	3.4	0.5	20	40	140	11	470	50
			90	1.16	BHP	9.8	2.8	0.8	31	33	150	14	660	54
Taiwan														
24	U	H	75 P	0.48	B	12.8	0.8	0.3	13	10	190	8	310	29
	U	S	74 P	0.41	Y	7.8	0.8	0.2	8	5	210	3	170	18
	U/A	S/H	74 P	0.43	N	10.3	1.1	0.4	10	9	210	6	260	26
Thailand														
31	U/A	···	77 S	0.53	FBN(E)	10.4	5.6	2.9	47	38	180	6	320	70
			78 S	0.54	B(E)	10.4	5.7	3.1	52	41	190	7	330	73
Turkey														
33	D	S	80 S	0.73	BHF	8.3	2.4	0.4	18	15	200	8	410	36
			78 S	0.48	S	7.0	0.5	0.2	12	12	160	3	240	21
			75 S	0.61	S	8.5	1.9	0.3	14	12	170	7	330	30
			65 S	0.45	F	7.2	0.5	0.2	11	11	160	3	220	20
Venezuela														
···	···	···	···	0.40	Y(E)	12.1	2.6	1.9	27	28	130	8	180	47
···	···	···	···	0.56	YS	10.1	2.7	0.5	13	14	140	11	280	36
58	···	···	76 P84	0.53	BH	13.5	1.7	0.5	13	14	160	11	330	36
			P79	0.67	BH	13.5	2.7	0.7	19	19	170	12	390	45
Zaire														
162	U	H	76	0.53	BHY(E)	10.9	4.3	2.1	33	48	220	8	290	63

[a] Ash, protein, vitamin, and mineral contents reported on a 14% moisture basis.
[b] In some cases, flour production had to be estimated on the basis of mill capacity or amount of wheat used × extraction rate. In Ecuador, South Africa, and Turkey several flours are included under a single production figure.
[c] Ar = Argentina, A = Australia, C = Canada, D = domestic, F = France, U = United States, I = imported but origin unknown. A blend of wheats from different countries is shown with slash.
[d] H = hard, S = soft, H/S = hard/soft blends.
[e] S = Straight grade, P = patent with patent percentage following if provided, SS = stuffed straight (straight grade stuffed with high ash clears).
[f] B = White pan bread, H = hearth type breads (includes French and Italian types, flat breads, and chapattis), F = family flour (all-purpose flour for home use), C = cakes, S = cookies, crackers, biscuits, and other low-sugar chemically-leavened products, Y-pastries and other sweet goods, P = pasta, N = noodles, E = flour enriched or fortified with added nutrients.
[g] Relative density in the flour sample of the eight nutrients compared to an estimated maximum value (100) of whole wheat.

denominator term $\Sigma (W_i/D_i)$ became constant (equal to 18.5), thus reducing the formula for S to:

$$S_{flour} = 100 \sum (F_i/D_i) / 18.5 = 5.4 \sum (F_i/D_i) \quad (2)$$

RESULTS AND DISCUSSION

Nutrient Composition

A total of 95 flour samples were collected in 30 different countries. The analytical data of the individual flours and the production data supplied by the mills are given in Table I. In view of the great potential diversity of the technological production methods and the variability in composition of parent wheats, drawing general conclusions involves a certain degree of risk.

Table II provides mean nutrient contents of flours grouped according to ash content. The well-known relation between ash content, extraction rate, and nutrient content is clearly evident. If one assumed that distribution of the mineral components in the wheat kernel did not vary substantially and that essentially similar milling streams were selected in blending the flours, the ash index would also reflect the degree to which the flours were refined by milling.

The protein content of flours did not vary as much as one might expect, perhaps because of efforts by the milling industry to meet a certain common protein level in flours. High ash content in many of the flours indicated that the protein flour level was reached by milling relatively low protein wheats and/or blends with extraction rates sometimes higher than customary in the United States.

The vitamins (B_1, B_2, niacin) and minerals (Fe, Zn, Mg) were positively correlated with the total mineral content of flours as indicated by the ash content. On the other hand, calcium showed only a slight increase with the ash content of flours, confirming a similar finding of Lorenz et al (1980) with U.S. flour samples.

Extraction Rates and Flour Production

Reported extraction rates tended to drop at first with decreasing ash contents but leveled off at about 74% and corresponding 0.6% ash content (Table II). Only two countries (Iran and Peru) reported an extensive use of extraction rates over 80%. Most countries used rates within the 72–78% range. A number of samples were classified as patent grade, indicating a further refinement to achieve low ash in the flour.

Production Data

Table I contains estimated volumes of flour production (1,000 metric tons/year) for those samples for which pertinent information was supplied. These figures reflect sizes of the mills. Using country averages to fill the missing data, the annual production represented by this collection was estimated to be 4.6 million metric tons (Table II).

The proportion of flours with high ash (over 0.8%) having a high rate of extraction (over 80%) and concomitantly higher nutrient retention is surprisingly small in this sample collection. Two-thirds of all flour samples, representing 75% of total production volume, had ash values below 0.6%. The reported extraction rates were 72–78%, similar to those used in the United States (Kulp et al 1980). Only eleven flours, from nine different countries, were enriched with supplemental nutrients. They represented 17% of total sampled flour production.

Nutrient Score

The S values of individual flour samples shown in Table I were computed as illustrated in Table III, using the data for unenriched flour taken from a recent survey of U.S. flours (Ranum et al 1980), as an example.

The individual flours in Table I show substantial variations in this value, ranging from 18 to 115 for unenriched flours. This wide spectrum is due to differences in flour type and milling extraction rates of the flour collection. The U.S. samples (Kulp et al 1980) were much more uniform in this respect, as evident from the milling extraction rates (73.5 ± 1.6%) and ash contents (0.44 ± 0.05% at 14% mb). The enrichment of flour may raise the S value over a hundred, depending on the level of supplementation used. One enriched sample in the present collection was rated 126 (Ecuador) while the U.S. flour fortified to meet the proposed National Research Council standards, (NAS/NRC 1974) would have S = 94 (Table III).

The nutrient score has the drawback inherent in any attempt to summarize a complex situation with a single number. Since S is a composite of a set of nutrients, it may cover up a deficiency in one or more of them. However, this is not a serious defect in the case of flour and wheat, because the changes in nutrient levels attributable to milling follow the same pattern.

The score is limited to eight nutrients by choice only; additional factors can be included when pertinent data become available. Inclusion of vitamins A, C, and D would have no effect on its value because these vitamins are absent in wheats and flours. The caloric content of flours is virtually constant, so the addition of this variable will not alter the score either. Of the remaining nutrients that may be included, none are as important in widespread nutritional deficiencies as the ones that are part of the score.

The level of each nutrient included in the score is based on analytical determinations, and no corrections were made for their biological availability. When, however, the biological availability values for flour and wheat nutrients are established, suitable coefficients can be inserted into the equations.

Other Nutrient Measurements Related to S

Mean Nutrient Value. S may be used to estimate the mean nutrient value (MNV) in terms of RDA. The following equation expresses this index for 100 g of flour and all eight nutrients:

$$MNV = \frac{10}{N} \sum (F_i/D_i) = 1.25 \sum (F_i/D_i) = 0.23S \quad (3)$$

TABLE II
Distribution of Mean Production and Nutrient Levels by Flour Ash Content

Flour Ash (%)	Samples (n)	Annual Production Volume (1,000 MT)	Annual Production Percent	Extraction Rate (%)	Protein (%)	Nutrient Content,[a] ppm B_1	B_2	Niacin	Fe	Ca	Zn	Mg	Nutrient Score
>1.5	3	70	1.5	···	11.0	6.3	1.1	34	42	220	23	890	82 ± 29
1.0–1.49	7	230	5	91	11.0	3.4	0.8	32	31	190	20	750	61 ± 7
0.80–0.99	5	400	9	80	11.3	2.9	0.6	23	22	160	15	500	47 ± 7
0.60–0.79	17	360	8	78	10.9	2.2	0.5	15	18	180	11	360	38 ± 6
0.50–0.59	29(9)[b]	1,470	32	74	10.9	2.0	0.5	14	17	190	9	310	35 ± 8
0.45–0.49	21(1)	1,180	26	75	10.3	1.1	0.3	11	13	160	6	250	27 ± 4
<0.45	13(1)	890	19	74	9.8	0.9	0.3	9	9	160	5	180	22 ± 4
Total	95 (11)	4,600 (840)	(18)										

[a] Unenriched samples only.
[b] Numbers in parentheses indicate enriched flours.

TABLE III
Nutrient Score (S) Calculations

Nutrient (i)	W_i[a] (ppm)	D_i[b] (mg/day)	W_i/D_i	Unenriched Wheat Flour F_i[c] (ppm)	F_i/D_i	F_i/W_i	NRC-Fortified Flour F_i[d] (ppm)	F_i/D_i	F_i/W_i
Thiamin	4.5	1.5	3.00	1.3	0.87	0.29	6.4	4.26	1.42
Riboflavin	2	1.7	1.18	0.4	0.24	0.20	4.2	2.33	1.98
Niacin	60	20	3.00	11.9	0.60	0.20	53	2.65	0.88
Iron	40	18	2.22	11.2	0.62	0.28	35	1.96	0.88
Calcium	400	1,000	0.40	137	0.14	0.34	1,984	1.98	4.96
Zinc	40	15	2.67	7.3	0.49	0.18	22	1.47	0.55
Magnesium	1,500	400	3.75	225	0.56	0.15	440	1.10	0.29
Protein	15%	(6.5)[e]	2.31	10.8%	1.66	0.72	10.8%	1.66	0.72
Total			18.53		5.18	2.36		17.41	11.69
S[f]			100		28			94	
MNV[g]			23		6.5			22	
Mean INQ[h]			1.30		0.36			1.22	
Mean PNR[i]						29.5			1.46

[a] W_i = Maximum level of nutrient in wheat (Aykroyd and Doughty 1970, Lorenz and Loewe 1977, Watt and Merrill 1963, Ziegler and Greer 1971).
[b] D_i = U.S. recommended daily allowance (Code of Federal Regulations 1978).
[c] Mean levels of nutrients in U.S. and Canadian commercially milled wheat flours, as reported by Ranum (1980).
[d] Minimum nutrient levels proposed for flour by Food and Nutrition Board (NAS/NRC 1974).
[e] The U.S. recommended daily allowance for protein with the nutritional quality of wheat protein is 65 g/day. A D_i value of 6.5 is needed when the W_i or F_i value is in terms of percent rather than of ppm.
[f] S = Nutrient Score = $100\ \Sigma\ (F_i/D_i)/\Sigma\ (W_i/D_i) = 5.4\ \Sigma\ (F_i/D_i)$
[g] Nutritive value (percent of US RDA supplied by 100 g) = $10\ (F_i/D_i)$. MNV = Mean Nutritive Value for these eight nutrients = 0.23S.
[h] INQ = Index of Nutritional Quality = $0.56\ (F_i/D_i)$. Mean INQ = 0.013S.
[i] PNR = Percent Nutrient Retention from that in wheat = $100\ (F_i/W_i)$. Mean PNR = $(100/N)\ \Sigma\ (F_i/W_i)$. Mean PNR $\approx$S for unenriched flour.

Nutrient Density. This characteristic has assumed increasing importance in evaluating nutritional food quality, as is evident from recent statements of the Food and Drug Administration (Fed. Regist. 1980) that stress the nutrient-to-calories balance. This principle, expressed as the Index of Nutritional Quality (INQ) by Hansen (1973) and Wyse et al (1976), is the ratio of the percent of nutrient requirement to the percent of energy requirement provided by a quantity of food. The index can be related to S:

$$\mathrm{INQ} = \frac{F_i/D_i}{100\ (3.6)\ (10)/2{,}000} = 0.56\ (F_i/D_i) \qquad (4)$$

$$\text{Mean INQ} = \frac{\Sigma \mathrm{INQ}_i}{N} = \frac{(0.56)\ S}{(8)\ (5.4)} = 0.013\ S \qquad (5)$$

The mean INQ for the eight nutrients is related directly to S (equations 4 and 5) because caloric content of flour is fairly constant (3.6 kcal/g). The energy requirement of 2,800 kcal/g used by Hansen was altered to 2,000 kcal/g to conform with the FDA recommendations (Fed. Regist. 1980). These values have not been computed for the present set of samples but can readily be estimated from the S values.

Nutrient Score as an Index of Nutrient Retention. The nutrients of parent wheat are separated into flour and feed fractions by milling. The feed fraction receives a disproportional share because of the way the nutrients are distributed within the wheat kernel. These nutrients are considered lost in that they are removed from direct human consumption. The mean percent retention of nutrients in flour (mean PNR) can be defined as:

$$\text{Mean PNR} = \frac{100}{N}\Sigma\ (F_i/W_i) \approx S \qquad (6)$$

Although mean PNR and S are algebraically distinct, S provides values similar enough to mean PNR (within 2% error) in unenriched flour (Table III) to allow it to be used as an estimator of nutrient retention. This is because the decrease in vitamin and mineral contents of flour with increasing milling refinement is fairly uniform.

The mean S value of flour in this survey (excluding enriched samples and those with ash content above 0.6%) was 29, indicating that on the average, two-thirds of wheat nutrients were "lost" on milling.

Type and Origin of Wheat

A majority of the flours was milled from imported soft and hard wheat or from blends of imported and domestic wheats. Most of the foreign wheats came from the United States, with a few originating in Canada, Argentina, Australia, and France.

Flour Uses

Many flours were reported to have multiple uses, ranging from bread to pasta. No connection was obvious between the type of flour (as indicated by its ash and protein contents) and the type of product in which the flour was used.

Government Regulations

About 50% of the countries reported that the government regulated the price of flour and wheat and less than 50% that it regulated the price of bread. Four countries indicated that the government required enrichment of flour.

SUMMARY

A survey of the composition of 95 flours and of milling practices covering 30 different countries is reported.

A single value, in which wheat of a reference composition was given a score of 100 (nutrient score), was devised to summarize the nutrient profile of flours. Using this index, average flour (normal extraction, unenriched) comprised two-thirds of the flours tested and had a nutrient score of 29, indicating that approximately one-third of wheat nutrients was retained in the flour. Increase in nutrient level by application of high extraction rates (above 80%) or by enrichment with minerals and vitamins was practiced in only one-third of the flour production. The most common milling extraction rates were 72–78%. Variation in nutrient composition was most evident in ash, mineral, and vitamin values and least apparent in the protein content of flours. Generally, the flours were milled for multiple use purposes. This survey covered mostly large mills; the effect of small mills that produce high extraction flours from domestically grown wheats could not be evaluated.

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