SELENIUM IN WHEATS AND COMMERCIAL WHEAT FLOURS

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ABSTRACT

Samples of hard and soft wheat as well as commercial flours milled from these wheats originating from 16 states and Canada were analyzed for selenium. Selenium content in hard wheat ranged from 0.05 to 1.09 μg/g and in soft wheats from 0.02 to 0.13 μg/g. The flour had a selenium content of about 50% of the respective wheat sample. Selenium content in hard wheat flour ranged from 0.03 to 0.78 μg/g and in soft wheat flours from 0.01 to 0.02 μg/g. Selenium in flour decreased as extraction percentage of the patent decreased.

Selenium deficiencies in man have not been reported (1), nor have studies been reported on availability of selenium in wheat to humans (2). Cases of selenium toxicity have occurred, however, in persons living in seleniferous areas and consuming locally grown foods. Symptoms described include discolored and decayed teeth, yellow skin color, chronic arthritis, brittle nails, edema, and gastrointestinal disorders (1).

Recent reports indicate that people who live in an area of the country abundant with selenium in the soil are much less likely to die of heart attacks, strokes, aneurysms, and other blood pressure diseases. They are also less likely to get cancer of the pharynx, esophagus, stomach, small and large intestine, and bladder—parts of the body that would come in contact with dietary selenium (3,4).

Areas also exist where soils are deficient in selenium, in part due to leaching and rainfall runoff, whereas in other areas selenium content in soil is excessive and makes the associated vegetation toxic to animals (5,6). Large areas in the Western United States, especially east of the Rocky Mountains, have seleniferous soils. In the north central and northeastern states, surface soils are generally lower in selenium.

Thus, the selenium content of foodstuffs has taken on a new significance, and is particularly important in populations in which usually nonvariable diets rely heavily on a few commodities.

In a recent study of the selenium content of common foods, wheat provided the largest amount to the diet (1). Previous studies of the selenium content of wheats and flours were conducted 30–40 years ago. In these studies, selenium content of wheats obtained in random selection from various parts of the world ranged from 0.1 to 1.9 ppm (7). Maximum quantities of selenium in Saskatchewan (8) and U.S. wheats (9) were approximately 4 ppm. Moxon *et al.* (10), however, later reported values as high as 63 ppm. Wheat bran was shown to contain the highest amount of the element, and flour the lowest, which Ferretti and Levander (11) confirmed in a more recent study.

With the introduction of new wheat varieties and modifications in agronomic practices, changes in mineral and selenium composition are possible. The purpose of this study was to determine the selenium content of a variety of wheats and the flours resultant therefrom produced in different parts of the United States and Canada.

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TABLE I
Selenium in Hard Wheats and Flours

	Grain				Flour				
Mill Location	Type[a]	Protein[b] (%)	Ash[b] (%)	Selenium (μg/g)	Extraction Percent of Patent	Application	Protein (%)	Ash (%)	Selenium (μg/g)
Kansas	HRW	12.10	1.62	0.30±0.04	94.0	Bread	11.17	0.46	0.21 ± 0.02
	HRW	12.39	1.69	0.27±0.05	95.0	Bread	11.47	0.44	0.22 ± 0.03
	HRW	11.80	1.60	0.31±0.01	96.0	Bread	10.94	0.44	0.31 ± 0.00
	HRW	12.13	1.61	0.20±0.03	96.0	Bread	11.60	0.49	0.18 ± 0.01
Montana	HRW	12.74	1.37	0.85±0.10	94.8	Bread	12.09	0.45	0.60 ± 0.08
North Dakota	HRS	13.42	1.56	0.43±0.09	98.0	Bread	12.91	0.51	0.37 ± 0.02
	HRS	14.60	1.75	0.53±0.09	100.0	Hearth	14.02	0.53	0.52 ± 0.06
	HRS	13.39	1.53	0.54±0.10	76.0	Bread	11.99	0.43	0.30 ± 0.03
South Dakota	HRS	14.66	1.65	0.68±0.08	100.0	Hearth	13.81	0.49	0.61 ± 0.09
Minnesota	HRW	10.88	1.52	0.83±0.12	96.8	Family	10.04	0.41	0.68 ± 0.07
	HRS	14.50	1.72	0.70±0.06	100.0	Hearth	14.04	0.57	0.60 ± 0.04
	HRS	14.07	1.61	0.53±0.04	98.0	Bread	13.38	0.51	0.52 ± 0.03
Idaho	HRW	11.26	1.56	0.10±0.00	100.0	Family	10.02	0.40	0.09 ± 0.02
	Durum	12.75	1.74	0.12±0.01	71.6	Macaroni	11.92	0.44	0.07 ± 0.03
Washington	HRS	12.98	1.53	0.64±0.03	96.0	Bread	12.05	0.48	0.57 ± 0.10
Texas	HRW	11.15	1.62	0.25±0.01	95.0	Family	10.17	0.44	0.21 ± 0.04
Arizona	HRW	11.62	1.37	0.05±0.00	100.0	Family	10.76	0.50	0.03 ± 0.01
Eastern Canada	HRS	12.69	1.62	0.79±0.11	80.0	Family	12.04	0.50	0.64 ± 0.06
	HRS	13.21	1.51	0.61±0.08	52.0	Family	11.79	0.39	0.57 ± 0.05
	HRS	13.60	1.55	0.58±0.04	nd[c]	Family	12.00	0.43	0.59 ± 0.02
	HRS	13.62	1.43	0.61±0.02	74.0	Hearth	13.25	0.54	0.53 ± 0.02
	HRS	13.20	1.38	1.09±0.16	59.0	Bread	12.92	0.47	0.35 ± 0.03
	HRS	13.23	1.47	0.74±0.11	71.5	Bread	12.45	0.49	0.61 ± 0.07
Western Canada	HRS	13.04	1.38	0.79±0.09	81.0	Bread	12.76	0.50	0.60 ± 0.04
	HRS	15.01	1.49	0.74±0.07	nd	Hearth	14.67	0.47	0.78 ± 0.10

[a]HRW = hard red winter, HRS = hard red spring.
[b]On 14% moisture basis.
[c]nd = not determined.

MATERIALS AND METHODS

Samples of 25 hard wheats and 14 soft wheats as well as commercial flours milled from these wheats were collected from mills throughout the United States and Canada after the 1975 harvest. The wheat samples represented various classes of wheat grown in the two countries. The flours milled from these wheats were of different extraction and percent of the patent, and were milled for specific bakery applications.

Moisture, protein, and ash content of the wheats and flours was determined using approved methods of the American Association of Cereal Chemists (12). Protein is expressed as N × 6.25 for grains and as N × 5.7 for flours.

For the determination of selenium, 1-g samples of wheat or flour were digested for 10 hr with 5 ml of perchloric acid in 50-ml volumetric flasks. The solutions in the flasks were brought to volume with deionized water. The concentration of selenium was then determined in the diluted solution using hydride generation in conjunction with flame atomic absorption (13).

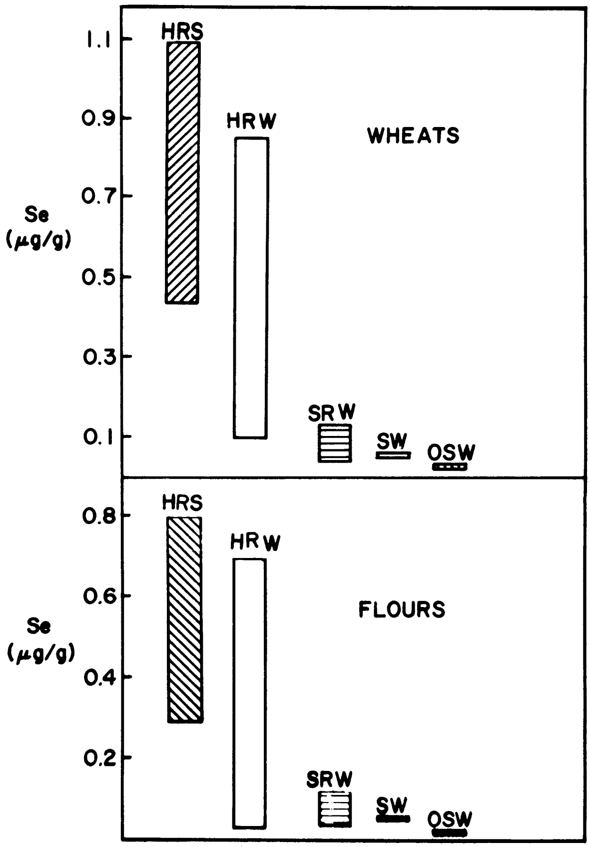

Fig. 1. Selenium content of different classes of hard and soft wheats and flours.

Materials from the National Bureau of Standards (NBS) with a certified selenium concentration were also included and were subjected to the same procedure. The materials and the percent of recovery of selenium were as follows:

NBS Standard Materials	*Se Content*	*Recovery of Se (%)*
Orchard leaves	0.08 μg Se/g	85.5
Bovine liver	1.10 μg Se/g	89.5
NBS coal	2.10 μg Se/g	101.5

Known amounts of selenium (0.1 and 0.5 μg/g, respectively) added to grain samples were recovered at 102.5%.

All analyses were done in duplicate.

With a 1-g sample, the sensitivity of this method is 0.015 μg. The data were analyzed statistically using a t-test. Correlation coefficients between selenium content of wheats and flours and the percent of protein and ash, respectively, were calculated. Multiple regression equations are presented to estimate the amount of selenium in hard and soft wheat flours based on the selenium content of the grain and the extraction percent of the patent.

RESULTS AND DISCUSSION

Hard Wheats and Hard Wheat Flours

The selenium content of hard wheat grain and hard wheat flours, grouped together according to mill location, are given in Table I. Values for selenium in the grain ranged from 0.05 to 1.09 μg/g and in flours from 0.03 to 0.78 μg/g. These values fall within the range of values reported in the literature (7,8,11) for selenium in wheats and flours.

The Canadian wheats averaged the highest amounts of selenium followed by wheats grown in the northern states of the United States. Wheat samples from Minnesota averaged 0.69 μg/g; from the Dakotas, 0.55 μg/g; from Montana, 0.85 μg/g; and from Washington, 0.64 μg/g of selenium. In general, soils in certain areas of these northern states contain higher selenium amounts than do soils in other areas of the United States (5,6). This probably results in a relatively higher uptake of the element by plants growing in these northern areas, although the translocation of selenium is not directly proportional to the total selenium

TABLE II
Statistical Evaluation of Selenium Content of Hard Wheats and Flours

	Wheat Class[a]	Number of Samples	Mean Se (μg/g)	Standard Error	T Value	Two-Tail Test	Correlation Coefficient[b] Protein (%)	Correlation Coefficient[b] Ash (%)
Grain	HRW	9	0.351	0.097	−3.02	0.006	0.3800	0.1950
Grain	HRS	16	0.647	0.050	−3.02	0.006	0.0987	−0.4108
Flour	HRW	9	0.281	0.073	−3.16	0.004	0.1295	−0.3950
Flour	HRS	16	0.531	0.043	−3.16	0.004	0.4156*	0.4160*

[a]HRW = hard red winter, HRS = hard red spring.
[b]* = significant at 5% level.

content in the soil (7). The selenium content was intermediate in wheats grown in Kansas and lowest in those from Idaho and Arizona.

The range of selenium values for each wheat class is shown in Fig. 1. Hard red spring (HRS) and hard red winter (HRW) wheats showed a significant difference ($\alpha = 0.05$) in selenium content (Table II). There were no significant correlations between selenium in grain and the protein and ash content, respectively, however.

Selenium content of the hard wheat flours, given in Table I, were generally lower than those of the wheats from which the flours were milled. The multiple regression equation is: Flour selenium = 0.726−0.808 (grain selenium) −0.0075 (extraction percent of the patent) −0.0172 (grain selenium × extraction percent of the patent). The ranges of selenium values in flours are shown in Fig. 1. There were significant differences ($\alpha = 0.05$) between the HRS and HRW flours as shown in Table II. The correlation coefficients between selenium in flours and the protein and ash content, respectively, of the flours were significant for the HRS flours but not for the HRW flours.

Ferretti and Levander (11) found a wheat flour fraction to contain 14% less selenium than did the original wheat. In our study, losses of up to 50% were found. The decrease in selenium content from wheat to flour, depended on the patent percent, indicating that selenium, as most mineral elements in wheat, is not evenly distributed in the wheat kernel. This is illustrated in Fig. 2. Selenium

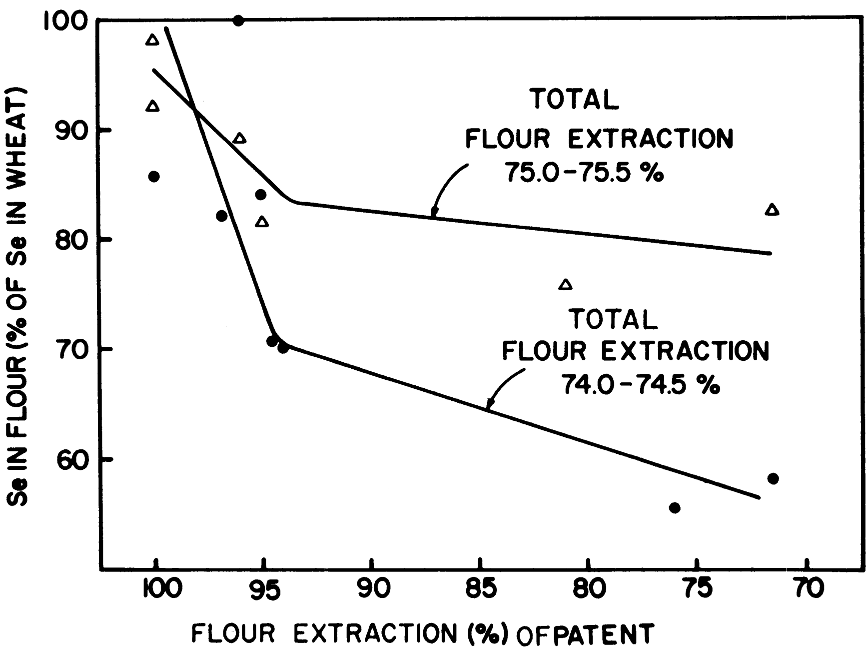

Fig. 2. Effect of total flour extraction and flour extraction percent of patent on selenium content of hard wheat flours.

TABLE III
Selenium in Soft Wheat and Flours

	Grain				Flour				
Mill Location	Type[a]	Protein[b] (%)	Ash[b] (%)	Selenium (μg/g)	Extraction Percent of Patent	Application	Protein[b] (%)	Ash[b] (%)	Selenium (μg/g)
Ohio	SRW	9.75	1.66	0.04 ± 0.01	100.0	Cookie, cracker	9.23	0.47	0.03 ± 0.00
	SRW	10.34	1.77	0.05 ± 0.00	35.0	Cake	7.67	0.41	0.03 ± 0.00
	SRW	10.28	1.71	0.09 ± 0.02	100.0	Cookie, cracker	8.93	0.41	0.05 ± 0.01
	SRW	10.35	1.70	0.08 ± 0.02	49.6	Cake	8.49	0.33	0.06 ± 0.01
Illinois	SRW	9.80	1.70	0.05 ± 0.00	65.0	Cake	7.97	0.33	0.04 ± 0.00
Indiana	SRW	9.88	1.74	0.13 ± 0.03	nd[c]	Cookie, cracker	8.51	0.49	0.12 ± 0.03
Idaho	SW	10.15	1.61	0.06 ± 0.01	50.3	Cake	7.90	0.36	0.05 ± 0.01
Missouri	SRW	10.15	1.68	0.12 ± 0.04	100.0	Cookie, cracker	9.23	0.47	0.06 ± 0.02
Washington	W	9.65	1.40	0.07 ± 0.02	58.5	Cake	7.98	0.39	0.07 ± 0.01
Tennessee	SRW	10.10	1.68	0.08 ± 0.00	82.0	Family	7.93	0.36	0.05 ± 0.00
	SRW	10.75	1.71	0.03 ± 0.00	20.0	Cake	7.83	0.33	0.02 ± 0.01
Mississippi	SW	10.19	1.66	0.05 ± 0.01	100.0	Cookie, cracker	8.56	0.38	0.05 ± 0.02
Eastern Canada	OSW	10.47	1.64	0.02 ± 0.01	10.0	Cake	8.07	0.37	0.01 ± 0.00
	OSW	10.00	1.73	0.03 ± 0.01	100.0	Cookie, cracker	8.82	0.49	0.02 ± 0.00

[a]SRW = soft red winter, SW = soft white, W = white club, OSW = Ontario soft winter.
[b]On 14% moisture basis.
[c]nd = not determined.

content of the hard wheat flours decreased as both the total flour extraction and the flour extraction of the patent decreased.

Soft Wheats and Soft Wheat Flours

The selenium content of soft wheats is given in Table III. Soft wheat grain values ranged from 0.02 to 0.13 $\mu g/g$ of selenium. These values are within the range of values found for soft wheats in the literature (14).

The range of selenium values within each class of soft wheat is illustrated in Fig. 1.

Compared with the hard wheats, each of the soft wheats contained significantly ($\alpha = 0.01$) lower amounts of selenium. The lower selenium content of soft wheats is probably due to the location at which the wheats were grown. The areas in the United States and Canada producing soft wheats generally have a low selenium content in the soil (6).

The selenium content of wheat flours, given in Table II, was lower than that of wheat grain from which the flours were milled. The range of selenium values for flours was between 0.01 and 0.12 $\mu g/g$ as illustrated in Fig. 1. The multiple regression equation is: Flour selenium = −0.0193 + 1.250 (grain selenium) −0.00876 (grain selenium × extraction percent of the patent) + 0.000371 (extraction percent of the patent).

Correlations between the selenium content of soft wheats and soft wheat flours and the respective protein and ash contents of wheats and flours were not significant.

CONCLUSIONS

The selenium content of wheats presently produced in the United States and Canada fell within the range of values reported for varieties grown 30–40 years ago (7,9). None of the wheats contained the element at a level that could produce toxic effects (9). Soft wheats contained significantly less selenium than did hard wheats. Milling of the wheats into flours caused a decrease in selenium that depended on flour extraction percent of the patent.

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