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Effect of Milling and Processing on the Selenium Content of Grains and Cereal Products

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The selenium content of grains and of the products and cereals derived from these grains was determined fluorometrically. Wheat flour and farina contained 14 and 29% less selenium, respectively, than the original raw wheat. Corn meal, flour, and grits contained 10-28% less selenium than did the raw corn. Milling of oats and rice caused little change in selenium concentration of those grain fractions destined for consumer use. Little or no decline in selenium concentration occurred during the manufacture of nonsugared corn or wheat breakfast cereals. There was a significant decrease in the concentration of selenium in sugared corn and sugared wheat breakfast cereals which was apparently due to dilution of selenium by the sugar. The decrease in selenium concentration in consumer products due to milling or processing of grains appeared to be less than that reported with several other nutritionally essential trace elements.

Selenium poisoning of farm animals due to the consumption of seleniferous plants grown on soils containing high levels of the element has long been recognized as a practical agricultural problem in certain regions of the United States (Moxon and Rhian, 1943; Rosenfeld and Beath, 1964). Because of the toxicological significance of selenium, analytical surveys were carried out to ascertain the selenium content of feedstuffs grown in seleniferous zones (Lakin and Byers, 1941; Smith and Westfall, 1937). Later research, however, has shown that the element can also have beneficial nutritional effects when present in the diet in trace amounts (Schwarz and Foltz, 1957), and selenium deficiency is now also considered a practical agricultural problem in some areas of the United States and some other parts of the world (Kubota *et al.*, 1967; Muth *et al.*, 1967). Although no selenium requirement has been established for humans, considerable experimental evidence indicates that the levels of 0.1 ppm of selenium in the feed for livestock and 0.2 ppm in the feed for turkeys will prevent deficiencies (Oldfield *et al.*, 1971). Because of the newly discovered nutritional importance of selenium, analytical surveys have been performed on foods and feedstuffs from nonseleniferous areas to determine whether or not dietaries contain adequate amounts of this essential trace element (Arthur, 1972; Morris and Levander, 1970; Oelschlager and Menke, 1969; Suchkov, 1971).

Grains, grain products, and cereals are important components of most ordinary diets, but the processing of grains can result in lower concentration of many nutritionally desirable trace elements in the flour (Czerniejewski *et al.*, 1964; Schroeder, 1971). The purpose of this work was to determine whether the processing of grains resulted in any decrease in selenium.

EXPERIMENTAL SECTION

Description of Samples. The samples of original raw grains and grain products were collected by the millers on the same day of the milling operation so that any day-to-day variation in the selenium concentration of the samples obtained would be minimized. A balance flow sheet which showed the yield of each product obtained in any given process batch was also provided by the manufacturers. If the sample was not already in a finely ground state as received, a 20-g subsample was ground in a Wiley mill and mixed thoroughly. All samples were stored at −6° a 10-30% decrease in the selenium concentration of the consumer product. This finding is in agreement with a

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Table I. Selenium Content of Wheat Fractions

Wheat fractions	% of starting material	Moisture, % as received	μg of Se/g wet basis	% of total Se
Raw wheat	100.0	11.8	0.332	100.0
Wheat flour[a]	72.7	12.2	0.286	63.0
Farina	3.0	13.6	0.235	2.2
Screenings	2.3	8.7	0.371	2.6
Ground wheat feed	22.0	11.3	0.435	29.0

[a] Used in ready mix formulas.

Table II. Selenium Content of White and Yellow Corn Fractions

Corn fractions	% of starting material	Moisture, % as received	μg of Se/g wet basis	% of total Se
White corn, #2 grade				
Raw corn	100.0	14.5	0.187	100.0
Corn flour	10.5	6.8	0.175	9.8
Corn meal	47.0	12.3	0.169	42.5
Grits, degerminated	17.4	12.5	0.182	17.0
Mill hominy feed	10.5	8.7	0.268	15.0
Mill germ	12.2	7.8	0.361	23.5
Screenings	2.4	12.3	0.162	2.1
Yellow corn, #2 grade				
Raw corn	100.0	15.3	0.226	100.0
Corn flour	7.4	12.0	0.164	5.4
Corn meal	58.8	6.0	0.163	42.4
Grits, degerminated	7.4	12.0	0.157	5.1
Mill hominy feed	11.0	16.4	0.272	13.2
Mill germ	12.8	16.1	0.313	17.7
Screenings	2.6	12.9	0.114	1.3

until analyzed. No information was available concerning the geographical origin of the grains, but the samples represented typical commercial blends.

Selenium Analysis. The selenium content of triplicate 1-g samples of each product was determined by the fluorometric technique of Hoffman *et al.* (1968) as modified by Morris and Levander (1970). Although all samples were analyzed as received and the results expressed on a wet basis, the per cent moisture values were included in the tables for computing the selenium values on a dry basis if desired.

RESULTS AND DISCUSSION

Wheat. The data in Table I indicate that there are 14 and 29% decreases in concentration of selenium in the wheat flour and farina fractions, respectively, when the processed fractions are compared with the raw wheat. An increase in the selenium content of ground wheat feed and screenings used for animal feed was noted. Overall, the selenium concentration was rather even in the various grain fractions. If one considers the human nutritional requirement to be similar to that of animal species, then the concentration of selenium present in the processed fractions would be considered nutritionally adequate.

Corn. Yellow corn had a slightly higher concentration of selenium than white corn (Table II). The results for corn were similar to those obtained with the wheat. That is, the selenium content of the white and yellow corn fractions intended for consumer use (flour, meal, and grits) was 10–28% lower than of the raw corn from which they were derived, while the fractions to be used for animal feed (mill hominy feed and mill germ) had higher selenium values. Also, as for wheat, the amount of selenium in all of the fractions was probably nutritionally adequate.

Table III. Selenium Content of Oats Fractions

Oats fraction	% of starting material	Moisture, % as received	μg of Se/g wet basis	% of total Se
Green oats (uncleaned)	100.0	9.6	0.581	100.0
Regular oat flakes	20.0	6.2	0.680	23.4
Quick oat flakes	31.0	7.9	0.613	32.7
Oat flour	3.0	7.8	0.714	3.6
Miniature oat flakes[a]	2.0	7.5	0.824	2.8
North Star (by-product)	6.0	7.3	0.660	6.9
Light oats (by-product)	7.0	8.6	0.510	6.2
Hulls (by-product)	26.0	6.7	0.206	9.3
Loss	5.0			

[a] Contain slightly more bran and germ than either regular or quick oat flakes.

Table IV. Selenium Content of Rice Fractions

Rice fractions	% of starting material	Moisture, % as received	μg of Se/g wet basis	% of total Se
Rough rice	100.0	10.2	0.074	100.0
Brown rice	79.5	10.7	0.081	87.0
Milled rice	70.5	11.0	0.075	71.5
Hulls	20.5	7.4	0.030	8.3
Bran	8.0	8.1	0.156	16.9
Loss	1.0			

Oats. The data in Table III show that for oats the by-product fractions that are used for animal feed (North Star, light oats, and hulls) had somewhat lower average concentrations of selenium than those fractions destined for consumer use. Here again, no severe decreases in selenium concentration were encountered in any fraction, and all the fractions contained nutritionally adequate levels of selenium.

Rice. Removal of the hulls from rough rice caused a slight increase in the selenium content of the resultant brown rice since the hulls themselves contain very little selenium (Table IV). On the other hand, milling the brown rice to remove the bran brought the overall selenium level of the milled rice back down to the level of the starting material as the selenium concentrated somewhat in the bran. With the exception of the bran, all the rice fractions analyzed would have to be considered only marginally adequate in selenium.

Cereals. Table V shows that the selenium concentration in the sugared corn cereal was approximately 40% less than that in the corn grits from which it was made. Most of this decrease was apparently due to dilution of the selenium by the sugar. Even so, the level of selenium in the grits was high enough so that the concentration of selenium in the sugared cereal was still nutritionally adequate. Of course, if the concentration of selenium in the original grits was only marginally adequate in selenium, the final sugared product would then be nutritionally inadequate in the element. The sugared wheat cereal and its parent durum wheat followed a similar pattern, since the concentration of selenium in the cereal was 65% less than that of the original wheat. As above, most of the decrease could be attributed to dilution by the sugar. There

Table V. Selenium Content of Cereals

Grain and cereal	Moisture, % as received	μg of Se/g wet basis
Corn grits, popping	12.5	0.304
Sugared corn cereal	4.4	0.189
Durum wheat	10.0	0.894
Sugared wheat cereal	3.1	0.317
Raw rice	12.2	0.261
Rice breakfast cereal	7.2	0.208
Soft white winter wheat	16.0	0.045
No. 1 wheat cereal, shredded	4.0	0.043
Raw whole wheat	13.2	0.042
No. 2 wheat cereal, shredded	5.1	0.049
Corn grits, flaking	13.6	0.027
Corn flakes	2.5	0.043

was a 20% decrease in selenium concentration when raw rice was processed into a rice breakfast cereal and, here again, the concentration of selenium in the original rice was high enough so that the rice cereal still contained ample amounts of selenium. Essentially, no decrease in selenium concentration due to processing occurred in the manufacture of the two shredded wheat cereals and corn flakes. However, the original grains of these three cereals contained very low levels of selenium so that the final cereal products contained nutritionally inadequate amounts of the element.

Our work shows that the processing of grains results in previous study which showed that the milling of whole wheat resulted in a 16% decrease in the concentration of selenium in the patent flour (Schroeder *et al.*, 1970). However, these decreases observed with selenium are not nearly as great as those seen with some other nutritionally essential minerals. For example, Czerniejewski *et al.* (1964) reported decreases of over 80% in the concentrations of cobalt, manganese, and magnesium when wheat was processed into flour. They also noted decreases of over 65% in the concentrations of copper, iron, and zinc. In our study, the cereals that were analyzed and found to be low in selenium were milled from grains that were initially low in selenium. Although one would expect that the interregional shipment of grains would probably ensure adequate amounts of selenium in grain products, certain low values found in this study indicated that such is not necessarily the case. Our results also indicated that in most cases the selenium was distributed rather evenly throughout the kernel of the grain. The high concentration of selenium in the rice bran was in accord with the results obtained by Moxon *et al.* (1943) who also found high concentrations of selenium in bran of wheat. The selenium that was lost to the consumer due to milling appeared in the by-products used in animal feeds, and therefore some of this selenium would probably be in the meat ultimately utilized by the consumer.

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