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Selenium supplemented fertilization - effects on the selenium content of foods and the selenium intake in Finland

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Introduction

In the 1970s results of the several studies indicated that in Finland the availability of selenium (Se) to plants was low due to the climatic and geochemical reasons. The Se content of domestic animal feeds and foods was very low and attention was given to the possible health effects of the low average Se intake of the population, only about 0.02-0.03 mg per day (Koivistoinen, 1980, Mutanen, 1984). In 1984 an official decision was made by the Ministry of Agriculture and Forestry to supplement compound fertilizers with sodium selenate to improve the quality of Finnish foods. The objective was to guarantee the adequate Se contents in agricultural products and to increase the average Se intake of the population to the recommended level. Since the beginning of the Se supplementation the Se levels in soils, fertilizers, feeds, basic foods, human serum and the average Se intake has been monitored. During this 20-year period the Se supplementation level has been revised twice. First two supplementation levels were used: 6 mg/kg for fertilizers intented for hay and fodder production and 16 mg/kg for fertilizers intented for cereal production. In 1990 uniform 6 mg/kg level was applied for all fertilizers and in 1998 the supplementation level was raised to10 mg/kg.

Se content of 15 basic foods were monitored regularly first in University of Helsinki (1984-1996), then in the Agrifood Research Finland (1998-) (cereals, wheat and rye flour and bread, milk, cheese, eggs, fish, potato, white cabbage) and in the National Veterinary and Food Research Institute (meat and liver). Organically grown foods were studied during 2001-2002. Occasionally some other food items were analyzed.

Results

The effect of Se fertilization was distinct. In the growing season 1985 the average Se content of spring cereals increased over 20-fold, from 0.01 to 0.23 mg kg^{-1} dw and remained at the level of 0.20-0.30 mg kg^{-1} dw during the years when supplementation level was 16 mg kg^{-1} fertilizer (Ekholm, 1997). Winter cereals were not affected as much as spring cereals due to the different cultivation and fertilization practice. Only Se supplementation of nitrogen fertilizer in 1996 has raised the Se content of winter cereals to about 0.1 mg kg^{-1} dw. In 2004 (supplementation level 10 mg kg^{-1} fertilizer) the average Se content of domestic cereals were approximately 0.1 mg kg^{-1} dw which was the original target value (Table I). However the variation between the farms was large <0.01-0.30 mg kg^{-1} dw.

Selenium contents of flours and breads (Table 1) have increased 10-20-fold. However, Se contents of flours and bread does not necessarily correlate with the Se content of domestic grain, but is also affected by the proportion of imported grain in the milling. During the years of crop failure the amount of imported grain can be as high as 100%. Recently most of the imported grain has been of European origin, where the Se content is often lower than in Finnish grain. Thus the high proportion of imported grain lowers the Se content of flours and breads (Eurola et al., 2003). In organic cultivation Se content of cereals was low, about 0.01-0.02 mg kg^{-1} dw. At the moment it is not permitted to add Se to organic fertilizers and the Se supplementation does not reach organically grown plants.

Table 1. Se content of wheat and rye grains in Finland in 1984 and 1998-2004.

Year	Selenium content mg kg^{-1} dw.					
	n	Spring wheat	n	Winter wheat	n	Rye
Silo samples from mills						
1984[a]	12	0.012 ± 0.007			10	0.009 ± 0.003
1998	3	0.076 ± 0.011	3	0.052 ± 0.010	2	0.066 ± 0.000
1999	4	0.130 ± 0.010	2	0.097 ± 0.025	1	0.120
2000	3	0.160 ± 0.014	2	0.130 ± 0.008	2	0.110 ± 0.006
2001	4	0.160 ± 0.050	3	0.091 ± 0.022	3	0.130 ± 0.027
2002	3	0.180 ± 0.034	3	0.100 ± 0.010	2	0.070 ± 0.023
2003	3	0.120 ± 0.008	3	0.085 ± 0.007	2	0.075 ± 0.005
2004	3	0.140 ± 0.035	2	0.076 ± 0.051	2	0.092 ± 0.029
Farm samples						
1984						
1999	13	0.150 ± 0.021	13	0.120 ± 0.015	22	0.130 ± 0.083
2000	14	0.190 ± 0.082	14	0.110 ± 0.042	12	0.110 ± 0.048
2001	21	0.130 ± 0.080	14	0.140 ± 0.051	15	0.084 ± 0.063
2002	44	0.150 ± 0.075	15	0.130 ± 0.059	20	0.072 ± 0.057
2003	32	0.140 ± 0.070	21	0.058 ± 0.032	27	0.079 ± 0.042

[a] Ministry of Agriculture and Forestry 1994

Milk was the first foodstuff indicating the effect of Se supplementation. Se content of milk doubled immediately when the outdoor feeding season begun and reached later average level of 0.2 mg kg-1 dw. The Se content of milk varies according to the season, being highest in the indoor feeding season and beginning to decrease in the outdoor feeding season. Present Se contents of milk, cheese and other basic foods are presented in table 2.

The Se intake meets well the international and national recommendations in Finland. The estimated average daily Se intake was slightly under 0.070 mg/day /10 MJ in 2004. It satisfies RDA and DRI daily Se intake recommendations of 0.055 mg. The most important Se sources are milk and other dairy products, meat and meat products. Together they account for nearly 70% of the total Se intake.

In Finland the supplementation of fertilizers with Se has proved to be an effective and safe way to improve the Se intake nationwide. Uniform geochemical conditions make the system relatively controlled. In this method plants take up selenate and convert it to organic Se compounds, mainly selenomethionine. This increases the Se content of foods/feeds of both plant and animal origin and have positive effect on human and animal Se intake.

Table 2. Se content of basic foods in Finland in 1975/77 and 2004.

Food	Se content mg kg^{-1} dw.			
	n	Mean 1975/77[a]	n	Mean 2004
Milk, standardized 3.5% fat	19	0.02	16	0.220
Milk, standardized 1.5% fat	-	-	16	0.180
Cheese, Edam-type	5	0.07	16	0.330
Eggs	4	0.41	16	1.010
Rye bread	7	0.02	30	0.058
Rye flour	10	0.01	6	0.054
Wheat bread	5	0.01	17	0.099
Wheat flour	9	0.02	10	0.110
Potato	20	<0.01	4	0.033
White cabbage	5	<0.01	4	0.160
Bovine meat	32	0.04	10	0.340
Bovine liver	8	0.24	25	0.950
Pig meat	4	0.20	16	0.460
Pig liver	4	1.38	29	1.110
Rainbow trout, farmed	6	0.76	4	0.750
Baltic herring	5	0.78	12	0.740

[a] Koivistoinen, 1980

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