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Zinc in the food chain: biological importance

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Objective. The zinc content in the Earth's crust amounts to 70 mg Zn/kg. Worldwide, the calculated mean level of zinc in soil is 64 mg/kg. The zinc content of the flora varies significantly with the geological origin of the soil, the age, species and part of plants. The weathering soils of the Triassic time (Keuper, Muschelkalk and Bunter), boulder clay and loess produce a vegetation low in zinc, whereas the vegetation of the weathering soils of syenite and phyllite is rich in zinc. Leaf-rich species of plants store more zinc than those rich in stems. Seeds and grains are poorer in zinc than leaves. With increasing age, the zinc concentration of annual plant species decreases significantly.

Materials and methods. After dry ashing of cleaned samples at 450 °C, zinc content was determined by flame atomic absorption spectroscopy (AAS) (Carl Zeiss Jena, AAS 3) and inductively coupled plasma atomic emission spectroscopy (ICP-AES) (Spectroanalytical Instruments Kleve, Spectroflame–D) (Röhrig 1998). Both analytical methods delivered similar results with a deviation of ±5%. The accuracy of the analytical methods was checked with the reference material ARC/CL, Total diet reference material (HDP)

Results. Spices and herbs are rich in zinc, but without importance for zinc supply. Ecologically grown herbs and vegetables contain a quarter less zinc than their conventionally grown counterparts. The phosphate fertilisation applied in conventional farming adds zinc to the soil, whereas long-time ecological farming depletes zinc. Generally, vegetables are rich in zinc. Potatoes, cabbage, carrots, kale, kohlrabi and onions deliver 18 to 30 mg Zn/kg DM, pulses and radish 30 to 50, and lettuce, cauliflower, cucumber, spinach and especially asparagus 50 to 100 mg Zn/kg DM.

Conclusions. On average, starch- and sugar-rich foodstuffs are poor in zinc (1 mg Zn/kg DM in starch). Flour and other farinaceous products, cake, rolls and bread supply 6 to 18 mg Zn/kg DM, pearl barley, oat, flakes and pulses contain 20 to 40 mg Zn/kg DM. Cereals, flour and pastry made from ecologically farmed grain contain more zinc than those made from conventionally farmed grain. Cereals not milled to a high extraction rate contain higher shares of bran, which contribute higher zinc contents.

Key words: zinc, food, vegetables, ecologically produced, plants, animals, flora and fauna

INTRODUCTION

Zinc (Zn) has been used unintentionally for the production of bronze since the 4th century B. C. As a free metal, zinc was produced in India as early as in the 13th century and in Europe at the beginning of the 16th century. It was rediscovered in 1746 by Marggraf when he heated calamine with charcoal. Today, more than 7 million tons of zinc are produced worldwide. References to the medical and biological uses of zinc appeared in the papyrus of Ebener von Nürnberg written about 1500 A.C. In this document, the topical use of zinc in the form of calamine was recommended as a therapy to heal lesions around the eye (7, 11). In the flora and fauna, zinc plays an important role as an essential (and toxic) trace element in all living systems from bacteria to plants, animals and man. It is an essential co-factor for enzymes controlling numerous cellular processes in plants and animals, including DNA synthesis, growth, reproduction, behavioural response, and development. Zinc is less toxic than other metals (cadmium, lead). Zinc plays an important role in the nutrition and health of plants, animals and man. The task of our research was the analysis of zinc transportation in the food chain of animals and man, and the balance and requirement of this trace element in man.

MATERIALS AND METODS

After dry ashing of cleaned samples at 450 °C, zinc content was determined by flame atomic absorption spectroscopy (AAS) (Carl Zeiss Jena, AAS 3) and inductively coupled plasma atomic emission spectroscopy (ICP-AES) (Spectroanalytical Instruments Kleve, Spectroflame–D) (13). Both analytical methods delivered similar results with a deviation of ±5%. The accuracy of the analytical methods was checked with the ARC/CL, Total diet reference material (HDP)" (11). Table 1 informs about the materials analysed. Analysis of the influence of the geological origin of soil on zinc content in the vegetation was carried out with ubiquitously spread plant species such as field red clover in buds, meadow red clover in blossom, rye in blossom, and wheat in shooting. Samples were collected all over Germany with the help of phenological maps (6) and geological ordnance survey maps (scale 1:25000). Generally, the plants were gathered when rye was in blossom. The geological origin of the sites was checked with pickup stones.

Table 1. **Species, origin and table numbers of the investigated samples**

Kind of samples	Table	Number of samples
Indicator plants, Germany	3	5803
Feeds and foodstuffs	4	113
Indicator plants, Hungary	5	453
Age of plants	6	144
Species and parts of plants	7	419
Winter grazing of game	8	626
Flour, farinaceous products, bread, cake	9	231
Conventionally and ecologically grown products	10	204
Sugar, honey, jam, cocoa, coffee, black tea	11	81
Conventionally and ecologically grown products	12	176
Spices and herbs	13	267
Conventionally and ecologically grown products	14	172
Fruits	14	141
Conventionally and ecologically grown products	16	97
Vegetables	17	384
Conventionally and ecologically grown products	18	173
Total	**–**	**9484**

The influence of the age of plants on the zinc content of the flora was investigated in lucerne, wheat, couch grass and field red clover on six different sites of the upper Muschelkalk in Thuringia between the end of April and June 11th.

The individual results were analysed with the help of the Fox Pro database system (version 2.6 for Windows, Microsoft Corporation). The statistical calculation was carried out with SPSS/PC (version 6.01 for Windows, SPSS Inc.), using the t test, variance analysis, and the smallest limit difference (SLD).

RESULTS

The influence of the geological origin of the habitat

The abundance of zinc in the Earth's crust averages 70 mg/kg. Zinc seems to be distributed rather uniformly in magnetic rocks (40–100 mg/kg), with a slight increase in mafic rocks (80–120 mg/kg) and a slight decrease in acidic rocks (40–60 mg/kg). Zinc concentrations in argillaceous sediments and shales are enhanced, ranging from 80 to 120 mg/kg, while those in sandstone and carboniferous rocks range from 10 to 30 mg/kg only.

The mean total zinc content in surface soils of different countries ranges from 17 to 125 mg/kg. Highest mean contents were reported for some alluvial soils, while lowest values were found for light mineral and light organic soils. Grand mean zinc for soils worldwide may be calculated as 64 mg/kg. Calcareous soils and a pH above 7 lower the zinc intake of plants. Zinc plays essential metabolic roles in the plant, the most significant being its activity as a component of a variety of enzymes (dehydrogenases, peptidases, proteinases and phosphohydrolases). Zinc also plays an important part in nucleic acid synthesis (18). Most plant species and genotypes have a great tolerance of excessive amounts of zinc. Chlorosis, mainly in new leaves, and depressed plant growth are the common symptoms of zinc toxicity. Most commonly, however, the upper toxic levels in various plants range from 100 to 500 mg/kg dry matter (9).

It is assumed that zinc content in plants varies considerably, reflecting different factors of various ecosystems and genotypes. The geological origin of the soil is one of the strongest influences on zinc concentrations in plants. The correlation coefficient of zinc content in the indicator plants wheat, rye, field red clover and meadow red clover varied between 0.61 and 0.87 in rye and wheat. The high correlation coefficients (average 0.75) of the used indicator plants demonstrates the qualification of these species for this purpose. The correlation coefficients for iron (0.38),

Table 2. **Correlation coefficients of the indicator plants grown on soil of the same geological origin**

Plant species	**(n)³**	**p²**	**y**	**r¹**
Meadow red clover : field red clover	(17)	< 0.001	17.6 + 0.44x	0.82
Meadow red clover : wheat	(15)	< 0.05	15.8 + 0.23x	0.61
Meadow red clover : rye	(14)	< 0.01	13.8 + 0.32x	0.74
Field red clover : rye	(21)	< 0.001	–2.59 + 0.78x	0.77
Field red clover : wheat	(22)	< 0.001	4.29 + 0.55x	0.71
Rye: wheat	(22)	< 0.001	6.28 + 0.71x	0.87

r¹ = correlation coefficient. p² = significance level, Student's t test. (n)³ = number of samples.

Table 3. **Influence of the geological origin of the site on the relative zinc content of the flora (n 5803)**

Geological origin of the site	**Relative index**
Syenite weathering soils	100
Phyllite weathering soils	92
Granite weathering soils	85
Rotliegende weathering soils	84
Slate weathering soils (Silurian, Devonian, Culm)	82
Bog, peat	82
Deluvial sands (Pleistocene sands)	79
Gneiss weathering soils	75
Alluvial riverside soils (Holocene flood plains)	70
Loess	62
Boulder clay	61
Bunter weathering soils	61
Muschelkalk weathering soils	59
Keuper weathering soils	52

copper (0.48) and molybdenum (0.63) are lower. Only the correlation coefficients of iodine (0.83) and nickel (0.83) are higher (2).

The German habitat with the highest mean zinc content was assigned an index of 100, and the sites were related to it. It was demonstrated (Table 3) that the syenite weathering soils of Central Europe transferred most zinc to the food chain. Weathering soils of granite, Rotliegende and slate produce a vegetation with nearly the same zinc content (82 to 85 relative index), whereas loess, boulder clay and the weathering soils of the Triassic transfer lowest zinc concentrations to the food web.

Table 4 shows the influence of the geological origin of the soil on the zinc content of meadow grass, kohlrabi and potato. The plants growing on Muschelkalk and Keuper weathering soils stored only a third to a half of the zinc amounts found in those growing on syenite and phyllite weathering soils in Germany.

Table 4. **Influence of the site on the zinc content of feed and food plants (mg/kg dry matter, DM) (n113)**

Species (n)		**Site**			**Fp²⁾**	**%¹⁾**
		Rich	**Middle**	**Poor**		
Meadow grass	x³⁾	118	74	39	< 0.01	33
(18; 18; 6)	s⁴⁾	65	39	24		
Kohlrabi (6; 12; 6)	x	68	36	29	< 0.01	43
	s	24	16	4.5		
Potatoes (29; 12; 6)	x	31	20	17	< 0.05	55
	s	16	6.3	3.8		

%¹⁾ Rich = 100%, Poor = x%, Fp²⁾ = significance level in one-factorial or multiple variance analyses, x³⁾ = arithmetic mean, s⁴⁾ = standard deviation.

Table 5. **Zinc contents of indicator plants from Germany and Hungary (mg/kg dry matter, DM) (n 453)**

Species (n)	**Germany**		**Hungary**		**p**	**%**
	s	**x**	**x**	**s**		
Lucerne (66; 93)	3	33	27	6	< 0.001	82
Meadow red clover (1488; 21)	24	48	34	9	< 0.001	71
Field red clover (3270; 58)	17	38	30	6	< 0.001	79
Wheat (524; 202)	10	26	18	6	< 0.001	69
Rye (455; 79)	12	28	18	5	< 0.001	64

Table 6. **Influence of plant age on zinc contents in several plant species (mg/kg dry matter, DM) (n = 144)**

Species (n)	April 30	May 12	May 26	June 11	SLD[1]	%
Secale cereale L., rye, green (24)	43	35	28	20	9	47
Festuca eliator L., fescue grass (24)	45	38	34	22	12	49
Trifolium pratense, meadow red clover (24)	50	44	36	25	7	50
Trifolium pratense L., field red clover (24)	46	45	39	30	13	65
Triticum aestivum, wheat, green (24)	31	31	30	21	8	68
Medicago sativa L., lucerne (24)	39	36	38	30	8	77

[1] SLD = smallest limit difference.

Table 7. **Zinc contents of several species and parts of plants (mg/kg dry matter, DM) (n 419)**

Species (n)	x		s	Species (n)	x		s
Summer barley (50)	27	±	33	Couch grass (15)	19	±	5.4
Maize, corn (15)	36	±	13	Stone clover (19)	20	±	4.0
Winter barley grain(21)	39	±	11	White clover (27)	26	±	9.3
Wheat, grain (21)	39	±	11	Green maize (26)	32	±	16
Rape, seed (16)	39	±	39	Tansy (18)	34	±	11
Oat, grain (33)	45	±	21	Green rape (5)	40	±	5.4
Rye, grain (32)	48	±	20	Alsike clover (8)	64	±	29
Sweet lupine, seed (12)	56	±	6	Meadow grass (42)	88	±	57
Broad bean, seed (26)	89	±	16	Beet leaf (33)	173	±	224

Table 8. **Zinc contents of several winter grazing plants eaten by game (mg/kg dry matter, DM) (n = 626)**

Species (n)	x	Species (n)	x
Quercus petraea L., oak nut (24)	10	Vaccinium myrtillus L., bilberry bush(55)	67
Calamagrostis villosa G., (7)	25	Secale cereale L., rye green (23)	72
Fagus silvatica L., beech nut (11)	31	Picea omorica L., Serbian spruce bark (6)	73
Calluna vulgaris L., heather (45)	32	Brassica napus L., rape, green (27)	73
Sorbus aucuparia L., rowan tree bark (7)	36	Rubus idaeus L., raspberry shoots (44)	87
Fagus silvatica L., beech twigs (24)	37	Alnus glutinosa L., black alder bark (7)	88
Quercus petraea L., oak twigs (24)	49	Sorbus aucuparia L., rowan tree twigs (18)	108
Pinus silvestris L., pine twigs (57)	51	Salix caprea L., willow tree twigs (6)	177
Pinus silvestris L., pine bark (29)	54	Picea abies L., spruce bark (30)	185
Deschampsia flexuosa L., wavy hair grass(105)	58	Populus tremula L., aspen bark (7)	186
Picea abies L., spruce twigs (63)	66	Betula pendula R. L., birch bark (7)	252

In Hungary, the calcium-rich soils of the Hungarian plain produce feedstuffs with a significantly lower zinc concentration than do the more sandy German soils (Table 5). Lucerne, clover, green wheat and rye of this region contain 20 to 35% less zinc in comparison with the same species grown in Germany. The geological origin of the soil has a lasting influence on the zinc content of the vegetation.

The influence of plant age on zinc concentration in the flora

The age of the annual plant species influences the zinc concentration of most species significantly (Table 6). With age, the zinc content decreases significantly. The lowering of zinc concentration is, on average, more pronounced in grasses and less in leguminous plants and herbs. The zinc intake of young plants is very high. Later on, the assimilations dilute the zinc concentration of the plants (5); zinc is transported from the older leaves to the new leaves, flowers and seeds. The zinc supply of herbivorous game and domestic animals is best in early spring and decreases significantly from late spring to summer.

The influence of plant species and plant parts on zinc content

The zinc content of annual plant species and parts of plants varies between ~20 and ~200 mg/kg dry matter (Table 7). Highest zinc amounts are found in beet leaves, leaf-rich plant species or meadow mixtures, like young meadow grass, in which zinc concentrations vary extremely with the geological origins of the habitat (Table 3) and with plant age (Table 6). Most of the leguminous plants are poor in zinc (Table 5). On average, the zinc concentrations stored by seeds and grains are lower than those stored by leaves (Table 7). Highest zinc concentrations (mg/kg DM) are found in broad beans (89) and lupine seeds (>50), lowest ones in barley, corn and wheat grains (30). In comparison with leaves, the grains of cereals are poor in zinc.

The zinc content of the grazing of game is very important for their health. On average, zinc concentrations in grazing plants are surprisingly high (Table 8). Again, the nuts of oak and beech are poor in zinc (10 to 31 mg Zn/kg dry matter), while the barks of several tree species are rich in zinc (70 to 270 mg Zn/kg dry matter). Several kinds of twigs (bilberry bush, willow and others) store medium concentrations of zinc. The same is true for green rye and rape growing on fields, which accumulate 70 mg Zn/kg dry matter. During winter, the zinc supply of game covers their requirement (2, 4).

Zinc in vegetable foodstuffs

Beside the geological origin of the site where food and feed plants grow, the age and species of plants and the plant parts used, the factors varying the zinc concentration of foods ready for consumption include the system of farming (conventional and ecological farming) and the food processing technology. In these aspects we analysed the zinc contents of vegetable foodstuffs. Nine, six and varied numbers of samples were available for the investigations.

The zinc contents of farinaceous products, flour, bread, cake and pulses

Cereal products, cereals, bread, cake and legume seeds store between 1 and > 40 mg Zn/kg dry matter (Table 9). Poor in zinc are all starch-rich cereal products (maize starch, wheat starch, vanilla-flavoured blancmange powder), which contain 1 to 2 mg Zn/kg DM. Biscuit, wheat semolina, sponge cake, toast bread and wheat flour deliver 6 to 10 mg Zn /kg DM. Cake with egg topping, rusk, noodles, rolls, rice, wheat and rye bread and macaroni store 11 to 18 mg Zn/kg dry matter. Chocolate-flavoured blancmange powder, oat flakes and pulses contain 20 to >40 mg Zn/kg DM and are extremely rich in zinc. Chocolate-flavoured blancmange gets its high zinc concentration from the cocoa added.

Ecologically produced cereals, flour and pastry deliver significantly more zinc to humans (Table 10). Ecologically produced flour is not milled to a high extraction rate, so that it partakes of the high zinc content of the bran, as do bread, rolls and cake baked from it, as well as other farinaceous products made in this way.

In case of bread, we have to distinguish between wheat and rye bread on the one hand and crispy bread and whole meal rye bread on the other. As

Table 9. **Zinc contents of farinaceous products, flour, bread, cake and pulses in mg/kg dry matter (DM) and in 100 g fresh matter (FM) (n = 231)**

Foodstuff (n)		Zn mg/kg DM		Zn mg/100 g FM	DM %
		x	s	x	
Maize starch	(9)	0.90	0.20	0.079	88
Wheat starch	(9)	1.7	0.50	0.150	88
Blancmange powder, vanilla-flavoured	(9)	2.1	1.7	0.181	86
Biscuit	(9)	6.1	0.80	0.604	99
Sponge cake with crumble topping	(9)	6.1	1.9	0.518	85
Semolina, wheat	(9)	6.6	1.0	0.574	87
Sponge cake	(9)	7.0	1.4	0.518	74
Flour for dumplings	(9)	7.8	1.7	0.686	88
Toast bread	(9)	8.4	1.1	0.571	68
Ready-mix soups	(15)	10	2.3	0.900	90
Wheat flour (type 630)	(9)	10	2.5	0.860	86
Cake with egg topping	(9)	11	1.6	0.407	37
Rusk	(9)	12	1.2	1.13	94
Flour for pancakes	(9)	12	0.6	1.06	88
Noodles	(9)	13	2.1	1.17	90
Rolls	(9)	14	2.3	1.06	76
Rice	(9)	15	2.1	1.32	88
Wheat and rye bread	(9)	16	1.5	0.992	62
Macaroni	(9)	18	3.5	1.62	90
Blancmange powder, chocolate-flavoured	(9)	22	3.2	1.94	88
Pearl barley	(9)	24	5.5	2.11	88
Oat flakes	(9)	31	7.6	2.76	89
White beans	(9)	33	3.5	2.87	87
Oat pulp	(9)	34	0.7	3.03	89
Pea, peeled	(9)	42	2.9	3.70	88

Table 10. **Zinc contents of conventionally (c) and ecologically (e) grown farinaceous products, bread and flour, in mg/kg dry matter (DM) and in 100 g fresh matter (FM) (n = 204)**

Foodstuff (n, n)		Zn mg/kg DM		p	%[1)]	Zn mg/100 g FM		%[1)]
		c	e			c	e	
Cornflakes	(6,4)	3.9	6.1	<0.05	156	0.376	0.578	154
Semolina, wheat	(15,4)	6.6	24	<0.05	364	0.574	2.09	364
Biscuits	(6,4)	7.9	20	<0.001	253	0.782	1.84	235
Flour, wheat	(15,4)	10	17	<0.01	170	0.860	1.53	178
Rusk	(15,6)	12	24	>0.05	200	1.13	2.30	204
Noodle	(15,4)	13	40	<0.01	308	1.17	3.57	305
Rolls	(15,4)	14	26	<0.001	186	1.17	2.15	184
Rice	(15,4)	15	23	<0.001	153	1.32	2.01	152
Macaroni	(15,4)	18	36	>0.05	200	1.62	3.30	203
Wheat and rye bread	(6,4)	21	28	<0.05	133	1.31	1.77	135
Crisp bread	(6,4)	30	29	>0.05	97	2.84	2.76	97
Whole meal rye bread	(6,4)	33	31	>0.05	94	1.74	2.15	124
Oat flakes	(15,4)	33	31	>0.05	94	2.92	2.75	94
%		–	–	185	–	187		

[1)] Conventional © = 100 %; ecological (e) = x %

Table 11. **Zinc contents of sugar, candy, jam, honey, cocoa, coffee and black tea leaves in mg/kg dry matter (DM) and 100 g fresh matter (FM) (n = 81)**

Foodstuff (n)		Zn mg/kg DM		Zn mg/100 g FM	DM %
		x	s		
Sugar	(9)	0.6	0.2	0.059	99
Candy	(9)	1.2	1.0	0.115	96
Jam	(9)	2.5	1.1	0.140	56
Honey	(9)	3.5	2.0	0.256	73
Coffee	(9)	6.1	1.0	0.586	96
Chocolates	(9)	14	2.1	1.30	93
Milk chocolate	(9)	16	0.9	1.49	93
Black tea leaves	(9)	31	6.2	2.85	92
Cocoa powder	(9)	83	8.9	7.64	92

Table 12. **Zinc contents of conventionally and ecologically grown sugar, candy, jam, honey, cocoa, coffee and black tea leaves in mg/kg dry matter (DM) and in 100 g fresh matter (FM)**

Foodstuff (n, n)	Zn mg/kg DM				Zn mg/100 g		FM
	c	e	p	%	c	e	%
Sugar (15.4)	0.76	3.0	>0.05	395	0.075	0.299	399
Candy (15.4)	1.7	3.5	>0.05	206	0.164	0.336	205
Jam (15.4)	2.6	4.1	>0.05	158	0.144	0.150	104
Sugar, candy, jam, %	–	253	–	236			
Blancmange powder, vanilla-flavoured (15.4)	1.5	1.4	>0.05	93	0.129	0.123	95
Coffee (15.4)	6.1	5.9	>0.05	97	0.587	0.573	98
Honey (6.4)	6.3	1.5	<0.001	24	0.447	0.113	25
Chocolate cream (6.4)	11	16	<0.05	145	1.05	1.51	144
Milk chocolate (15.4)	14	15	>0.05	107	1.33	1.33	100
Blancmange powder, chocolate-flavoured (6.4)	15	13	>0.05	87	1.32	1.17	89
Black tea leaves (15.4)	34	37	>0.05	109	317	3.40	107
Cocoa powder (9.4)	83	69	<0.05	83	7.67	6.36	83
Blancmange to cocoa powder, %	–	93	–	93			

Table 13. **Zinc contents of spices and herbs in mg/kg dry matter (DM) and 100 g fresh matter (FM) (n 267)**

Foodstuff (n)		Zn mg/kg DM		Zn mg/100g FM	DM %
		x	s		
Pepper	(15)	13	3.8	1.14	88
Cinnamon	(15)	14	9.8	1.23	88
Onion leek	(8)	17	4.1	0.187	11
Paprika, sweet	(9)	21	7.0	1.85	88
Paprika, hot	(9)	23	7.0	2.02	88
Chive	(9)	46	17	0.460	10
	(34)	29	12	0.290	10
Parsley	(9)	76	10	0.836	11
	(33)	40	10	0.440	11
Marjoram	(61)	61	15	5.31	87
	(6)	39	6.2	3.39	87
Caraway	(15)	42	8.1	3.82	91
Mustard	(9)	47	5.3	1.18	25
Mustard seeds	(9)	51	6.9	4.74	93
Dill	(9)	124	129	1.24	10
	(17)	57	60	0.570	10

Table 14. **Zinc contents of conventionally and ecologically grown spices and herbs in mg/kg dry matter (DM) and in 100 g fresh matter (FM) (n 172)**

Foodstuff (n, n)		Zn mg/kg DM				Zn mg/100 g		FM
		c	e	p	%	c	e	%
Pepper	(15,4)	13	9.7	<0.05	75	1.15	0.870	76
Cinnamon	(15,4)	14	17	>0.05	121	1.23	1.50	122
Paprika	(6,4)	28	23	>0.05	82	2.49	2.02	81
Caraway	(15,4)	42	32	<0.05	76	3.78	2.92	77
Mustard	(15,4)	45	33	<0.01	73	1.14	0.860	75
Marjoram	(6,4)	39	38	>0.05	97	3.42	3.37	99
Mustard seeds	(15,4)	54	50	>0.05	93	5.02	4.57	91
Chive	(15,4)	39	38	>0.05	97	0.414	0.340	82
Dill	(15,4)	57	60	>0.05	105	0.570	0.654	115
Parsley	(15,4)	81	62	>0.05	77	1.44	0.879	61
%		–	–	90	–	88		

Table 15. **Zinc contents of fruits in mg/kg dry matter (DM) and 100 g fresh matter (FM) (n 141)**

Foodstuff (n)		Zn mg/kg DM		Zn mg/100g FM	DM %
		x	s		
Apple sauce	(9)	3.9	1.2	0.039	10
Apple	(9)	3.9	1.4	0.051	13
	(39)	3.0	2.4	0.039	13
Morello cherry	(7)	4.3	2.0	0.064	15
Sweet cherry	(8)	4.7	0.67	0.080	17
Pear	(10)	4.9	1.4	0.059	12
Orange	(9)	4.9	1.9	0.069	14
	(6)	7.0	2.6	0.098	14
Lemon	(9)	8.0	1.6	0.080	10
	(15)	8.8	8.3	0.088	10
Kiwi	(6)	9.3	8.9	0.149	16
Banana	(6)	11	8.6	0.198	18
Strawberry	(8)	13	5.7	0.143	11

Table 16. **Zinc contents of fruits from conventional and ecological farming in mg/kg dry matter (DM) and in 100 g fresh matter (FM) (n 97)**

Foodstuff (n, n)		Zn mg/kg DM				Zn mg/100 g		FM
		c	e	p	%	c	e	%
Apple	(15,4)	4.2	2.4	>0.05	57	0.051	0.025	49
Apple sauce	(15,4)	4.0	2.6	<0.01	65	0.059	0.030	51
Orange	(6,4)	7.0	5.4	>0.05	77	0.071	0.062	87
Pear	(6,4)	11	5.8	<0.05	53	0.134	0.073	54
Kiwi	(6,4)	9.3	7.3	<0.01	78	0.148	0.074	50
Lemon	(15,4)	8.8	8.3	>0.05	94	0.115	0.060	52
Banana	(6,4)	11	8.6	>0.05	78	0.202	0.136	67
%		–	–	72	–	59		

the latter kinds are produced from the whole grain, their zinc concentration is similarly high. The same applies to oat flakes.

Zinc content of sugar, candy, jam, honey, cocoa, coffee and black tea leaves

Like starch, sugar and sugar-rich products such as honey and jam contain <4 mg Zn/kg DM (Table 11). Coffee does not have a high zinc content either, but black tea leaves are rich, and cocoa powder is extremely rich in zinc.

Ecologically produced sugar is brown cane sugar, not beet sugar (Table 12). The zinc content of brown cane sugar delivers four times the amount of zinc to the food chain compared to white beet sugar. Ecologically produced candy and jam contain more zinc than their conventionally produced counterparts. The influence of the farming system on the zinc content is, with exeption of bee honey and black tea leaves, significantly limited by the different technologies of sugar production.

Zinc content of spices and herbs

Spices contribute only small amounts of zinc to human nutrition, although the zinc content of some spices is extremely high (Table 13). Relatively low zinc concentrations are found in pepper and cinnamon. All herbs and especially dill, but also marjoram, parsley and chive supply between 30 and 125 mg Zn/kg DM. Astonishingly, caraway and mustard seeds are also very rich in zinc.

Generally, after reunification of Germany (1990) the zinc concentration of the foodstuffs decreased. In case of chive, parsley, majoram and dill (Table 13), the differences were significant. On average, ecological farming lowers the zinc concentration of herbs and spices by approximately >10% (Table 14).

The ecological farming without fertilisation with zinc-rich phosphates lowers the bioavailability of zinc and decreases the zinc concentration of spices, herbs (Table 14), fruits (Table 16) and vegetables (Table 18). Pepper, caraway and mustard seeds of ecological farming stored significantly smaller concentrations than those of conventional farming.

Zinc content of fruits

On average, fruits are poor in zinc (Table 7). Their zinc contents vary between 4 and >10 mg Zn/kg DM. Apples, cherries and pears deliver between 4 and 5 mg Zn/kg DM to the food web, while kiwis, bananas and strawberries are richer in zinc (9 to 13 mg Zn/kg DM).

Generally, ecologically produced fruits deliver, on average, a quarter less zinc to the consumer (Table 16). Water content in the ecologically produced fruits is mostly higher than in conventionally grown fruits (Table 16). The difference in the zinc concentrations of the fruits of both farming systems relates to the increase in fresh matter.

Zinc content of vegetables

The zinc concentration in vegetables varied between 16 mg Zn/kg DM in potatoes and >90 mg/kg DM in asparagus. Asparagus is very rich in zinc. All other vegetables, with the exception of young carrots, are older and store zinc in much lower concentrations. Generally, all vegetables harvested at the end of the last century accumulated lower amounts of zinc than those collected 10 years before (Table 13).

Cabbage, kale, kohlrabi, onions and Spanish onions store between 20 and 30 mg Zn/kg DM. Pulses, radish and lettuce accumulate 30 and 50 mg Zn/kg DM. Lettuce, cauliflower, spinach and asparagus contain 50 to 100 mg Zn/kg DM and deliver much zinc to the food web of humans.

Like fruits and herbs, ecologically grown vegetables (Table 18) store a quarter less zinc in the dry matter and contain more water than conventionally grown plants. Fertilisation with phosphates delivers a lot of zinc to the soil in conventional farming, whereas prolonged ecological production exhausts the zinc content of the soil.

CONCLUSIONS

The weathering soils of Keuper, Muschelkalk and Bunter, boulder clay and loess produce a vegetation low in zinc. Leaf-rich species of plants store more zinc than those rich in stems. Seeds and grains are poorer in zinc than leaves. With age, the zinc concentration of annual plant species decreased significantly. The winter grasing of game is on average rich in zinc.

On average, starch- and sugar-rich foodstuffs are poor in zinc (1 mg Zn/kg DM in starch). Flour and other farinaceous products, cake, rolls and bread supply 6 to 18 mg Zn/kg DM, pearl barley, oat, flakes and pulses contain 20 to 40 mg Zn/kg DM.

Cereals, flour and pastry made from ecologically farmed grain contain more zinc than those made from conventionally farmed grain. Cereals not milled to a high extraction rate contain higher shares of bran, which contributes higher zinc contents.

Ecologically grown herbs, spices and vegetables contain a quarter less zinc than their conventionally grown counterparts. Phosphate fertilisation applied in conventional farming adds zinc to the soil, whereas long-time ecological farming depletes the zinc concentration.

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CINKAS MAISTO GRANDINËJE IR JO BIOLOGINË SVARBA

S a n t r a u k a

Darbo tikslas: Nustatyti cinko kieká maisto grandinëje ir ávertinti jo biologinæ svarbà. Cinko kiekis þemës plutoje siekia 70 mg/kg, dirvoþemyje – vidutiniškai 64 mg/kg. Cinko kiekis augaluose priklauso nuo dirvoþemio geologinës kilmës, augalo amþiaus, rûðies ir jo dalies. Eroduoti triaso periodo dirvoþemiai, rieduliø moliena ir liosas lemia maþà, o sienito ir filito dirvoþemiai – didelá cinko kieká augaluose. Lapuoèiai sukaupia daugiau cinko nei augalai, nepasiþymintys vešlia lapija.

Rezultatai. Sëklos ir grûdai sukaupia maþiau cinko nei lapai. Laikui bëgant cinko koncentracija vienmeèiuose augaluose labai sumaþëja. Gilës, buko sëklos, taip pat ir grûdai, sukaupia labai nedaug cinko. Krakmolingi ir cukraus turintys maisto produktai turi maþai cinko (1 mg/kg sausosios medþiagos (SM) kukurûzø krakmole, 3 mg/kg SM meduje). Miltuose ir kituose miltiniuose produktuose, pyraguose, bandelëse ir duonoje cinko yra 6–18 mg/kg SM, aviþø dribsniuose ir ankðtiniuose augaluose – 20–40 mg/kg SM.

Ið ekologiniuose ûkiuose uþaugintø grûdø pagamintose koðëse, miltuose ir teðloje yra daugiau cinko nei produktuose ið áprastuose ûkiuose uþaugintø grûdø. Rupiau sumaltuose grûduose yra daugiau sëlenø, o tai lemia ir didesná cinko kieká. Ekologiðkas rudas nendriø cukrus turi daugiau cinko nei tradicinis cukriniø runkeliø cukrus. Daug cinko yra prieskoniuose ir vaistaþolëse. Ekologiðkai auginamose vaistaþolëse ir darþovëse cinko ketvirtadaliu maþiau nei tradiciðku bûdu auginamose. Tradiciniame ûkyje naudojant fosfatines tràðas cinkas dar patenka á dirvoþemá, o ilgalaikis ekologinis ûkininkavimas sekina jo atsargas. Gausu cinko darþovëse: bulvëse, kopûstuose, morkose, lapiniuose kopûstuose, kaliaropëse ir svogûnuose – 18–30, ankðtinëse darþovëse ir ridikëliuose – 30–50, salotose, agurkuose, ðpinatuose ir ypaè ðparaguose 50–100 mg/kg SM.

Raktaþodþiai: cinkas, maistas, darþovës, ekologinë gamyba, augalai, gyvûnai