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Mineral and trace element content of various vegetarian foodstuffs available in Belgium

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Abstract Atomic absorption spectrometry was used to determine mineral (Na, K, Ca and Mg) and trace element content (Zn, Fe, Cu and Si) of various vegetarian foodstuffs in Belgium. Thirty-five commercially available products were analysed after a wet-acid destruction in a closed-vessel destruction bomb. Various important sources of the minerals and trace elements were identified. Since data for vegetarian foods in Belgium are non-existent, the concentration values are compared with the scarce literature data and particularly with levels found in the same products available in The Netherlands.

Key words Belgium · Minerals · Trace elements · Vegetarian foodstuffs · Atomic absorption spectrometry

Introduction

Vegetarian foodstuffs have become increasingly popular in Belgium in recent years for health, ecological, philosophical, and religious reasons. Even the omnivorous dietary pattern has changed, with an increase in the intake of plant-based products.

Such changes may alter the average content and bioavailability of trace elements in contemporary diets and, hence, the trace element status of selected groups.

Until now, data on mineral and trace element content of vegetarian foodstuffs available in Belgium have been non-existent. Only preliminary reports on daily dietary intake levels, by macrobiotics and vegetarians, have been reported for Se [1], Cu and Zn [2] and Mn [3].

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Therefore, in order to complete a food composition table for Belgium [4] we have analysed 35 common and widely available vegetarian products by atomic absorption spectrometry after wet-acid destruction in a closed-vessel destruction bomb.

Materials and methods

Materials. The various vegetarian foodstuffs were collected at different places in the Antwerp region (Belgium) at the beginning of September 1997. The types of food and brand names are summarized in Table 1. Since typical brand names would not translate well from the Dutch, a description of the basic substance is given.

Depending on the type of food, the samples were homogenized in a blender, of which different parts were Teflon coated. After weighing an exact amount of the non-prepared food the samples were freeze-dried (GTL, Leybold Heraeus) and afterwards homogenized in a polypropylene mortar with a polypropylene triturator.

Of the dried material, 0.4 g was put through a microwave oven digestion procedure using a Teflon-coated destruction bomb as previously described in this journal [5].

Methods. Analytical techniques and quality control for analysis of Ca and Mg [6], Na and K [7], Fe [8], Cu [9] and Zn [10] have been published elsewhere in this journal. For Si, only preliminary results are presented [11].

Validation of the method was carried out and the results are summarized in Table 2. Since no standard reference materials were available for Si, only recovery experiments were carried out.

Results and discussion

The water contents of the various foodstuffs were calculated after lyophilization and are presented in Table 1. For the two oily hazelnut spreads and especially for the two highly salted flavourings (Shoyu and Tamari) no water content could be determined.

Mineral contents (Na, K, Ca and Mg) and trace element contents (Zn, Fe, Cu and Si) of the foodstuffs are summarized in Table 1.

Table 1 Water, mineral and trace element content in 100 g fresh weight of 35 vegetarian foods

Sample	Whole grain (kamut)	Cereals (spelt)	Quinoa	Lentils	Azuki beans (red)	Chickpeas	Sesame seed (roasted)
Water (%)	5.9	7.8	9.4	7.5	5.7	4.9	1.7
Na (mg)	2.7	0.74	5.0	0.31	0.9	2.4	2.0
K (mg)	419	400	494	1007	1323	1004	512
Ca (mg)	26.7	25.8	33.7	53.4	81.2	115.4	1098.0
Mg (mg)	126.6	122.4	136.8	109.2	137.5	126.9	331.0
Zn (mg)	3.7	3.1	2.8	5.0	3.4	2.6	5.0
Fe (mg)	4.3	4.0	4.6	8.6	6.1	5.9	9.5
Cu (μg)	536	489	455	756	1046	701	1762
Si (mg)	1.4	2.6	1.9	2.2	1.1	3.1	2.5

Table 1 Continued

Linseed	Pasta (whole corn)	Pasta (whole corn)	Pasta (wheat)	Spaghetti (whole corn)	Spaghetti (wheat)	Hazelnut spread	Hazelnut spread (+fructose)
6.4	8.0	7.4	3.9	7.1	6.3	–	–
23.4	1.3	2.2	3.1	4.0	4.2	0.4	43.4
708	461	401	320	435	471	476	469
216.0	37.5	31.9	27.9	34.4	32.6	145.1	57.4
331.0	102.1	93.4	75.9	113.1	120.3	169.1	77.9
4.4	2.7	2.5	2.6	3.2	3.8	2.3	0.98
7.6	4.0	3.9	2.7	3.5	3.9	3.3	5.1
1209	457	433	440	496	967	1480	562
0.53	2.3	1.8	1.5	3.4	2.0	1.0	2.5

Table 1 Continued

Lima soya drink	Lima 3	Rice drink	Rice waffle	Rice waffle (biological)	Rice waffle (chocolate)	Rice crackers (hot)	Soya dessert
93.2	87.8	86.5	7.2	4.6	3.7	1.9	76.8
21.1	14.1	29.2	1.8	134	5.5	893	56.7
75	46	12	278	285	373	127	84
8.7	17.1	15.6	15.6	16.3	40.7	15.0	15.3
14.3	12.8	7.4	142.4	121.7	126.7	23.6	17.0
0.59	0.19	0.07	2.0	1.8	2.0	0.72	0.25
0.35	0.27	0.07	1.6	2.1	7.2	0.73	0.31
117	55	2	262	345	647	122	86
0.7	2.0	1.8	10.6	5.9	5.1	3.0	1.1

Table 1 Continued

Coffee (ersatz)	Cereal instant coffee	Barley (roasted)	Shoyu	Tamari (flavouring)	Miso	Agar-agar	Seitan (meat substitute)
1.5	1.5	3.8	–	–	40.2	2.3	76.4
90.4	82.3	8.7	5423	5273	4234	851	510
1481	1911	624	540	740	374	30	58
55.6	68.9	58.7	39.6	59.4	63.6	92.1	23.3
77.1	83.5	145.8	84.7	108.4	64.4	64.3	14.8
0.79	0.93	2.6	0.93	1.1	1.3	0.94	0.71
3.1	2.1	4.3	2.0	2.3	2.4	10.4	1.5
95	71	516	4	3	388	62	165
4.6	4.0	53.2	1.8	1.9	1.8	34.4	2.1

High values for Na were obtained for the meat substitute (Seitan), the Hummus sandwich spread, the agar-agar, the rice crackers (hot) and the Quorn. Both liquified soy products (Shoyu and Tamari) and the miso were brine solutions since more than 5% of the wet weight was Na.

The Azuki red beans and both the ersatz coffees were found to be important sources of K. It is quite remarkable that the agar-agar contained hardly any K.

Lentils, hazelnut spread, chickpeas and especially the sesame seed (roasted) were found to be rich in Ca and Mg.

Table 1 Continued

Tofu	Hummus (sandwhich spread)	Seitan (prepared)	Quorn (fungal proteins)
80.7	53.5	62.2	72.5
0.57	527	669	370
67	183	252	119
68.4	49.8	50.0	42.3
94.4	32.7	38.0	36.3
1.1	0.58	1.0	7.2
2.0	1.2	2.1	0.3
172	143	212	385
1.3	2.6	4.5	12.3

The various seeds (lentils, sesame, linseed), but especially the fungal proteins, used as ersatz meat (Quorn), were revealed as having the highest Zn levels, whilst lentils, sesame seeds, linseed and especially the agar-agar, due to the chlorophyl from the algae, were found to be important Fe sources.

For Cu, the seeds (sesame, linseed), the hazelnut spread and the red Azuki beans were found to be rich in this element. Both salty flavourings either do not contain Cu or Cu atomization was depressed by the high salt content. Standard addition on the Shoyu sample proved that the matrix did not produce a signal reduction and a similar slope of the calibration line was obtained compared to other less-salted foodstuffs.

Finally, high levels of Si were found in the rice waffles, the Quorn, the agar-agar and especially in the roasted barley.

Insofar as literature data were available and could be compared, i.e. where there was a consistent concentration expression (wet or dry weight content) or analytical technique (Si), these are included in Table 3. Values for cooked foods [21] are not included.

For several elements values found for Belgium were very similar to literature data, but the background of the product (country of origin, element content of the soil, species, preparation and storage conditions) can vary so greatly that this comparison was hardly relevant.

The levels found in some well-defined vegetarian products were compared with those found for the same product in a neighbouring country (The Netherlands). Here, in general, the variation in concentration levels was small (e.g. rice waffle), while for chickpeas the element content in the Belgian was much higher.

For tofu there were differences, which could be explained by the fact that this product has varying protein and water contents. The differences depend on the method of preparation, the type of coagulants used and the grade and protein contents of the beans. The Ca and Mg contents of tofu also varied considerably, according to the coagulant used. Sea salt coagulant is high in Mg [15].

For these reasons, the levels found in the various foodstuffs in relation to mineral and trace element adequacy in those population groups on the restricted vegetarian food pattern are discussed in detail.

Na and K

Miso, a fermentation product of salted soy beans and rice (or soy beans and barley) is one of the leading sources of sodium chloride for the Japanese. Homemade preparations contained more Na than store-bought preparations and a significant correlation was observed between Na intake via miso and death rate indices for cerebrovascular diseases [22].

The Chinese Na intake was derived from processed foods, monosodium glutamate and especially soy sauce (16%). The intakes of total Na, salt and soy sauce decreased as educational level increased [23]. The high Na levels of some products need particular attention.

Cereals and vegetables are the major sources of dietary K [23]. Although edible higher mushroom species are an important and valuable K source for human diets, as proven in Germany [24], the *Fusarium* species in the Quorn did not reveal a high K content.

Ca and Mg

Dairy products provide 70% of the dietary Ca of the population in the USA [25]. Relatively few non-dairy foods contain significant amounts of Ca [26] and it is

Table 2 Validation of the analytical procedure

	Spiked concentration (mg/kg)	Recovery (%)	Detection limit (μg/100 g fresh weight)	Reference material (mg/kg; certified)	Reference material (mg/kg; found)
Na	10 –30	103 ± 1	1.0	2420 ± 60[a]	2480 ± 20[a]
K	25 –75	107 ± 2	2.0	1330 ± 30[b]	1350 ± 40[b]
Ca	15 –45	103 ± 3	2.0	191 ± 4[b]	193 ± 4[b]
Mg	5 –15	97 ± 1	2.0	400 ± 20[b]	400 ± 10[b]
Zn	0.5– 1.5	98 ± 3	0.5	127 ± 16[a]	122 ± 1[a]
Fe	2 – 6[d]	101 ± 1	0.3	300 ± 20[c]	298 ± 12[c]
Cu	5 –15[d]	106 ± 5	0.1	12 ± 1[c]	12 ± 0.6[c]
Si	0.5– 2	97 ± 6	4.0	–	–

[a] Bovine liver (NBS 1577b); [b] Wheat flour (NBS 1567a); [c] Orchard leaves (NBS 1571); [d] μg/g (ppb)

Table 3 Literature data on mineral trace element content of vegetarian foods (mg/100 g fresh weight)

Food type	Reference	Na	K	Ca	Mg	Zn	Fe	Cu
Chickpeas	This study	2.4	1004	115	127	2.6	5.9	0.7
	NEVO \12]	8	297	46	43	1.7	1.8	–
	[13]	–	–	–	–	3.0	–	0.9
	[14]	–	–	157	122	3.2	5.1	0.6
	[15]	–	326	55	–	1.7	3.4	–
	[16, 17]	–	–	154	177	–	7.1	0.8
Lentils	This study	0.31	1007	53	109	5.0	8.6	0.8
	NEVO [12]	5	1000	80	400	–	5.0	–
	[14]	–	–	87	79	3.1	8.4	0.7
	[15]	–	249	25	–	1.0	2.1	–
	[16, 17]	–	–	44	88	3.5	8.7	0.7
	[18]	–	–	64	73	–	–	–
	[19]	–	–	–	–	3.7	–	1.0
Spaghetti (wheat)	This study	4.2	471	33	120	3.8	3.9	1.0
	[20]	0.6–2.2	146–207	13–19	30–56	0.9–1.5	2.6–4.0	0.25–0.33
Miso	This study	4.2	374	64	–	1.3	2.4	–
	[13]	–	158	68	–	6.5	3.6	–
	[21]	3.6–7.2[a]	–	–	–	–	–	–
		3.9–4.7[b]	–	–	–	–	–	–
Rice waffle	This study	13.4	285	16	122	18	2.1	0.35
	NEVO [12]	157[c]	303	18	132	2.0	1.5	–
Tofu	This study	0.6	67	68	94	1.1	2.0	0.17
	NEVO [12]	6	55	188	70	1.1	2.2	–
	[13]	–	4.2	12.8	–	0.73	1.9	–
	[19]	–	–	–	–	0.73	–	0.21
Sesame seeds (roasted)	This study	–	–	–	–	5.0	–	1.8
	[19]	–	–	–	–	7.2	–	2.5

[a] Home-made; [b] Store-bought; [c] Salted

therefore a challenge for individuals who exclude or limit consumption of dairy products to reach the recommended intakes of Ca, at least from natural foods.

Ca derived from plant sources is not only present in a less concentrated form but the bioavailability may be greatly reduced by fibre, phytate, and oxalate [15].

The Ca status of vegans and lacto-ovo-vegetarians may vary radically. The lacto-ovo-vegetarian diet contained significantly more Mg, Ca and K than a control omnivorous diet [27].

Vegetarian diets in Sweden provide a more than adequate amount of Mg, as discussed elsewhere [28].

Zinc

Vegetarian diets are potentially limited in Zn because foods that are considered to be the best sources of this trace element, such as meat, poultry, and seafood, are excluded [19].

Vegetarian diets in which meat products are replaced with soy-protein-based foods (e.g. tofu) may have a low Zn content with poor bioavailability due to their fibre and/or phytate contents [29]. Bioavailability can change, depending on the method of food processing used [30]. Recently we proved that the bioavailability of Zn from infant food on a soy base, available in Belgium, can be as good as or even better than from infant food on a cow's milk base [31].

Nuts, dried legumes, and whole-grain cereals are relatively good sources of Cu and Zn [32].

Iron

Restrictive vegetarian diets (e.g. macrobiotic) are associated with iron-deficiency anaemia. Non-heme (inorganic) Fe from plant sources is less well-absorbed than heme Fe from animal sources [33]. High levels of ascorbic acid in vegetarian diets may counteract the poor absorption of non-heme Fe and thus improve Fe status [34]. Western vegetarians who consume a variety of foods have a better Fe status than those in developing countries who consume a limited diet based on unleavened, unrefined cereals [35].

Copper

Whole grain cereals, legumes, nuts and some green leafy vegetables are abundant sources of these trace elements [32].

Hence, for Burundi the rural population was revealed as having a higher Cu intake than a middle class group [36]. The more elevated element concentration and the higher consumption of these food groups are responsible for the higher Cu intake by vegetarians in Sweden [37], vegetarian women in various countries [38–40], lacto-vegetarians in Sweden [41] and lacto-ovo-vegetarians in Canada [42] compared to non-vegetarians.

Pre-menopausal Indian vegetarians were shown to have lower Cu intake values than Caucasian vegetarians [43].

Silicon

Rich sources of Si are unrefined grains of high fibre content, cereal products and root vegetables [44, 45] and beer has also been mentioned [46].

Foods of animal origin, except skin (e.g. chicken), are relatively low in Si [44].

Since the diets of vegetarians are based mainly on grains and other plant products their Si intake can be expected to be higher than that of omnivorous populations. Some literature data on Indian and Chinese populations, whose diet is characterized by its low proportion of foods of animal origin, confirm this. The daily intake of Si was reported to be 139 mg in China [47] and 143–204 mg in India [48], while for Finland 29 mg was calculated as the daily intake [49]. Similarly low values were published for Great Britain and Japan, with even lower values (10 mg/day) for North America [50]. For Belgium preliminary results have been published elsewhere [11].

Information on the Si contents of foods and diets is summarized from the published literature [51], but includes no information on vegetarian food products, which were analysed in this study. Problems with the analytical procedure for Si (a lack of standard reference material, the risk of contamination by dust and the less sensitive colorimetric techniques used) mean that for the same material (e.g. raw carrots) concentration levels found varied from 0.1 mg/100 g to 17.1 mg/100 g [51]. Hence, no literature values for Si are included in Table 3.

The bioavailability of a number of minerals may be altered by the special characteristics of vegetarian diets. The possibility that plant-based diets may compromise mineral status is not discussed here, but the interested reader is referred to the literature [32, 33, 42, 52].

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