The Status of Micronutrients (Cu, Fe, Mn, Zn) in Tea and Tea Infusions in Selected Samples Imported to the Czech Republic

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Abstract

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A total of 30 tea samples of different origins, thirteen green tea samples, thirteen black tea samples, two semi-fermented tea samples and one white tea, imported to the Czech Republic, were collected and analysed for the total content of copper, iron, manganese, and zinc in tea leaves and tea infusions. The total contents of metals in tea leaves differ according to the type of tea (green or black) and are probably influenced by many other factors, e.g. soil properties. The total contents of Mn were much higher compared to the total contents of Cu, Fe, and Zn, and varied between 511–2220 mg/kg. To compare easily hot water soluble concentrations of Cu, Fe, Mn and Zn, 5 min, 60 min, and 24 h infusions were prepared. The extractability of the elements was in the order Cu > Zn > Mn > Fe. The proportions of the element contents in the infusion related to the respective total contents in leaves were 30 ± 16% Cu, 26 ± 10% Zn, 18 ± 10% Mn, and 1.5 ± 0.8% Fe, respectively. The results confirmed that tea infusion can be an important dietary source of Mn.

Keywords: tea; tea infusion; copper; iron; manganese; zinc; nutrient status

Tea is an infusion made from dried leaves of *Camellia sinensis* L. It is the most important species of all *Camellia* spp. used for beverages. Tea is an evergreen shrub indigenous to China and parts of India, which can be found in tropical, subtropical, and temperate regions. Tea is now grown all over the world but especially in China, India, Indonesia, Sri Lanka, and Japan. Tea is also successfully grown in Africa, namely in Kenya, Malawi, Zimbabwe, and South Africa (Greenop 1997). It grows best at lower temperatures (5–25°C), high relative humidity (80–90%), and high annual rainfall (around 1500–2000 mm). It favours a deep, well-drained, and acidic soil (Musgrave 2002). Given such conditions, tea will grow in the altitude of up to 2100 m, and just as with wine, the aspect, soil, altitude, and climate will affect the flavour and characteristics of the tea. The chemical composi-

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tion of tea leaves consists of tanning substances, flavonols, alkaloids, proteins and amino-acids, enzymes, aroma-forming substances, vitamins, minerals, and trace elements (Jha *et al.* 1996).

Among the minerals and essential trace elements, Ca, Na, K, Mg, and Mn are present in tea leaves at g/kg level, while Cr, Fe, Co, Ni, Cu, Zn are present at mg/kg level (Cao *et al.* 1998). Besides essential macro- and microelements, *Camellia sinensis* belongs to the plants that strongly accumulate aluminium at concentrations exceeding 1000 mg/kg in their leaves (Jansen *et al.* 2003). Aluminium in most of its forms presents no harm to living organisms. However, under certain conditions such as low pH, Al tends to form toxic species. These species are then potentially toxic to all living organisms, including humans (McLachlan 1995). Recent studies show that Al is involved in some important human pathologies, such as Alzheimer's disease, Parkinson's disease, and dialysis encephalopathy (Exley & Korchazhkina 2001). The total metal components in tea plants depend on many factors, primarily the age of the tea leaves, but also the soil conditions, rainfall, altitude, genetic make up of the plant etc.

The factors affecting the metal contents in tea leaves influence subsequently the metal concentrations in the infusion. The preparation method (infusion time, temperature, tea-water ratio) has also a great influence (Marcus *et al.* 1996). Tea polyphenols have a high affinity for metals and also for biological macromolecules such as alkaloids, carbohydrates and proteins (Yang *et al.* 2004). The prooxidant action of the tea polyphenols seems to be an important mechanism of their anticancer properties, and transition metals, especially copper, play a significant role in these processes (Azam *et al.* 2004). The distribution of other essential metal ions in tea infusions is also of great importance but does not seem to be well documented. Tea infusions could be a good dietary source of essential trace metals for humans. Powell *et al.* (1998) shows that one litre of tea infusion before digestion contains less than 6% of average daily intake of minerals, but under stimulated intestinal conditions, a single serving of tea will contribute to about 10% of the average daily dietary intake of Mn in a potentially bioavailable form (Table 1). For many people, tea drinking may be a major source of dietary Mn (Wrobel *et al.* 2000), as it is evident also in comparison with other beverages such as hibiscus and maté. However, the percentage of elements leached into the infusion is strongly related to the tannin content in the beverage; with lower tannin levels, better leaching was observed. Besides the beneficial effect of polyphenols such as tannic acid, an adverse effect exist of reduced iron absorption as demonstrated by Afsana *et al.* (2004). They observed that feeding a diet containing more than 10 g of tannic acid per kg of diet reduced the hemoglobin concentration, hematocrit, serum Fe concentration, and liver Fe level of rats due to a decreased Fe absorption. In contrast, the Zn, Cu, and Mn absorption was not affected by tannic acid feeding. Therefore, it is recommended to individuals with a high prevalence of iron deficiency to drink tea between meals, and to wait at least 1 h after eating before drinking tea (Temme & Van Hoydonck 2002; Nelson & Poulter 2004).

In this study, the total Cu, Fe, Mn, and Zn contents in the tea leaves, and the amounts of these elements available in the tea extracts were evaluated depending on the type of tea and on the method of preparation. Moreover, the possible impact of the tea drinking on the uptake of these elements is discussed.

Table 1. Concentrations of metals in tea infusion and contributions to average daily intakes (Powell *et al.* 1998)

Element	Average daily intake (range) (mg/day)	Elemental concentrations of tea infusions (mean) (mg/l)	Part of average daily dietary intake from 1 litre of tea (%)	Part of available element at intestinal pH (6.5) (%)	Available element from 1 litre tea as part of average daily dietary intake (%)
Al	5 (2–10)	2.94	58.8	4.8	2.82
Cu	2.5 (2–3)	0.05	2.0	45.3	0.91
Fe	15 (10–18)	0.006	0.04	< 5	< 0.002
Mn	4 (2–5)	4.6	115	39.8	45.8
Zn	15	0.19	1.3	33.7	0.44

MATERIAL AND METHODS

A total of 30 tea samples of different origins imported to the Czech Republic were collected and analysed. There were thirteen green tea samples, thirteen black tea samples, two semi-fermented tea samples and one white tea (Table 2). For the determination of the total element contents in tea leaves, aliquots (0.5 g) of the dried and powdered biomass were decomposed in 50 ml quartz-glass beakers at 500°C for 16 h on a hot plate and in a muffle furnace with a stepwise increase of the ashing temperature (Mader *et al.* 1998). The ash was then heated for 5–10 min at 100°C in 3 ml of *Aqua Regia* and than transferred quantitatively to test tubes and made up to 20 ml with deionised water. Tea infusions were prepared to test the solubility of the metals after (*i*) 5 min, (*ii*) 60 min, (*iii*) 24 h as follows: 1 g samples of tea were carefully weighed into standardised glass beakers. To

Table 2. Tea samples: type of tea, name, location, prevailing soil unit

Sample	Type of tea	Name of tea	Location	Soil unit
1	Black	Golden Nepal	Darjeeling	Acrisols
2		Gruzie OP	Caucasian	Arenosols
3		Kenya GFOP – 1 Milima	Kenya	Alisols
4		Ceylon OP Dimbula Uduwela	Sri Lanka	Acrisols
5		Pu – Erh	Yunnan, China	Alisols
6		Assam OP blend	Assam, India	Cambisols
7		Ceylon OP decaffeinated Superior	Sri Lanka	Acrisols
8		Gunpowder black	unknown	unknown
9		Nilgiri	South India	Acrisols
10		Turkey BOP	Turkey	Alisols
11		Darjeeling FF FTGFOP1 Lucky Hill Inbetween	Darjeeling	Acrisols
12		Golden Yunnan FOP	Yunnan, China	Alisols
13	Green	Formosa Gunpowder	unknown	Acrisols
14		Jade Arrow	unknown	Alisols
15		Bancha	unknown	Alisols
16		Java OP green	Indonesian Island	Acrisols
17		Japan Kokaicha	Japan	Luvisols
18		Lung Ching	Zhejiang Province, China	Alisols
19		China Sencha	China	Alisols
20		Darjeeling SFTGFOP Moondakotee	Darjeeling	Acrisols
21		Chun Mee	Chun Mee, China	Fluvisols
22		Vietnam Ché ngon So	Vietnam	Alisols
23		Bancha	Yunnan, China	Alisols
24		Yunnan green	Yunnan, China	Alisols
26	Semi-fermented	Ti Kuan Yin	unknown	Acrisols
27		Formosa Fine Oolong	Taiwan	Acrisols
28	White	Pai Mu Tan	Fujian, China	Alisols
29	Green	unspecified	China	Alisols
30	Black	unspecified	China	Alisols

extract the components of tea leaves, 50 ml of boiled distilled water was poured into each beaker after which they were covered with watch glasses. After the given time, the extracted solutions (tea infusion) were filtered through filter paper (blue label) into test tubes, and immediately measured. The pHs of the tea infusions were determined potentiometrically.

The contents of Cu, Fe, Mn, and Zn in the plant digests and tea infusions were determined using inductively coupled plasma optical emission spectrometry with axial plasma configuration (ICP-AES – Varian VistaPro, Australia), equipped with an autosampler SPS-5, at spectral line λ = 327.4 nm for Cu, 238.2 nm for Fe, 257.6 nm for Mn, and 206.2 nm for Zn, respectively. Aliquots of the certified reference material CRM CTA-OTL-1 Tobacco leaves were mineralised under the same conditions for the quality assurance of the analytical data of the total selected elements contents in tea samples. Statgraphics Plus 4.0 for Windows (MANUGISTICS 1997) was used to perform the statistical evaluation of the data where ANOVA multiple range test, 95% LSD, was applied for the evaluation of the data.

RESULTS AND DISCUSSION

During the literature review, it became apparent that not only Al, but also other beneficial and comparatively interesting trace metals were available in the tea plant and, therefore, in its infusions. Among them, copper, iron, manganese, and zinc are usually compared with regards to their total contents and easily soluble forms (Matsuura *et al.* 2001). The total contents of these elements determined in a set of tea leaves imported to the Czech Republic are presented in Tables 3–6. The contents of metals in the tea leaves can be arranged in the following order, with regards to their total contents: Mn > Fe > Zn > Cu. Saud and Oud (2003) reported the same conclusions in their study, and proved the ability of tea plants to accumulate metals, particularly Mn and Fe, and to a lesser extent Zn and Cu. In our results no statistically significant differences in the total contents occurred between black and green tea samples. Also Fernandez-Caceres *et al.* (2001) did not found any clear differences between the metal contents in green and black teas. The results summarising the element contents in the black tea samples produced in Turkey (Narin *et al.* 2004) showed lower Cu levels (10.4–24.8 mg/kg) and higher Zn levels (109.9–146.1 mg/kg) as compared to our results while Mn values varied in the same range (564–1082 mg/kg). Kumar *et al.* (2005) demonstrated wide ranges of Cu and Mn contents in tea samples produced in different countries which is confirmed also by our results. As mentioned above, the differences in the total contents could be influenced by many aspects: primarily the age of the tea leaves, but also the genetic make up of the plant, soil conditions, rainfall, and altitude. Marcus *et al.* (1996) stated that the metal contents in tea leaves differ according to the type of tea (green or black) and geological conditions. A study done by Fung *et al.* (2002) found that the element concentrations in different parts of the tea plant (young leaves, old leaves, branches) were different in different locations.

The pHs of the tea infusions were in the range of 4.04–5.08 (average value 4.42). Black tea was found to be more acidic (pH 4.3) than green tea (pH 4.5) while semi-fermented tea had the highest acidity of all (pH 4.2). White tea had a pH of 4.9. Matsuura *et al.* (2001) found that after brewing black tea, the pH of the tea infusion was 5.8, and suggested that the elements tested in the black tea may hardly be soluble at pH 5.8. But in the brewing method used in that study, the tea leaves were boiled for 5 min in water which is not a typical procedure for the tea preparation. A standard infusion would be to leave the tea to lixiviate for 3–5 min.

The easily hot water soluble forms of Cu, Fe, Mn, and Zn found in the tea infusions can be arranged in the following order, according to their contents determined: Mn >Zn > Cu > Fe (Tables 3 and 4). The studies done with regard to the extractability of metals in black tea (Odegard & Lund 1997; Matsuura *et al.* 2001) found the extraction efficiencies of Fe to be poor in comparison with the moderatly extractable Cu, Zn and Mn. The percentage of easily hot water soluble forms of Cu, Fe, Mn, and Zn, found in the tea infusions and related to their total contents in dry matter, can be arranged in the following order: Cu > Zn > Mn > Fe. The proportions of the element contents in the infusion from the respective total contents in leaves were 30 ± 16% Cu, 26 ± 10% Zn, 18 ± 10% Mn, and 1.5 ± 0.8% Fe, respectively. Matsuura *et al.* (2001) classified Mn and Zn as moderately extractable elements (20–55%), and Fe and Cu as poorly extractable elements (< 20%). These findings do not agree with our results in the case of Cu and Mn, however, the transfer ratio of each metal is dependent on the temperature and "strength" of infusion as well as on the kind of tea (Tascioglu & Kok 1998).

With Cu (Table 3), no significant difference exists between the 5 min and 60 min tea infusions. The Cu content dropped slightly from the 5 min to 60 min infusions but it rose again during the 24 h infusions. The slight drop in Cu concentration in 60 min as compared to 5 min infusion may be explained by large numbers of equilibria in tea solutions (both chemical and physico-chemical). There was a statistically significant difference between green and black teas in the 5 min infusion, with Cu content being higher in black teas. After the 60 min infusion, the Cu content was higher in black tea than in green tea, but the opposite was found in the 24 h infusion, with the green tea having a higher Cu content. With regards to Cu

Table 3. Total contents of Cu in tea leaves (mg/kg), concentrations of Cu in tea infusions in relation to extraction times (mg/l), and relative part of soluble Cu in tea infusions (%)

Sample	Total (mg/kg)	5 min		60 min		24 h	
		(mg/l)	(%)	(mg/l)	(%)	(mg/l)	(%)
1	27.8	0.441	79.3	0.120	21.6	0.204	36.7
2	13.8	0.155	56.2	0.143	51.8	0.016	5.8
3	38.1	0.159	20.9	0.142	18.6	0.122	16.0
4	27.1	0.308	56.8	0.102	18.8	0.043	7.9
5	19.0	0.117	30.8	0.133	35.0	0.057	15.0
6	31.1	0.207	33.3	0.232	37.3	0.071	11.4
7	36.2	0.176	24.3	0.172	23.8	0.132	18.2
8	31.7	0.149	23.5	0.165	26.0	0.151	23.8
9	31.5	0.265	42.1	0.060	9.5	0.134	21.3
10	13.4	0.090	33.6	0.172	64.2	0.115	42.9
11	26.0	0.072	13.8	0.116	22.3	0.113	21.7
12	28.0	0.260	46.4	0.159	28.4	0.178	31.8
13	22.0	0.140	31.8	0.189	43.0	0.285	64.8
14	24.0	0.191	39.8	0.095	19.8	0.138	28.8
15	18.2	0.033	9.1	0.157	43.1	0.196	53.8
16	29.0	0.191	32.9	0.275	47.4	0.232	40.0
17	25.8	0.173	33.5	0.036	7.0	0.221	42.8
18	22.8	0.186	40.8	0.096	21.1	0.209	45.8
19	20.0	0.061	15.3	0.019	4.8	0.153	38.3
20	37.6	0.084	11.2	0.111	14.8	0.094	12.5
21	23.7	0.127	26.8	0.205	43.2	0.197	41.6
22	21.4	0.080	18.7	0.034	7.9	0.140	32.7
23	14.6	0.082	28.1	0.119	40.8	0.101	34.6
24	28.5	0.101	17.7	0.072	12.6	0.210	36.8
26	9.0	0.120	66.7	0.041	22.8	0.083	46.1
27	26.7	0.087	16.3	0.317	59.4	0.135	25.3
28	19.7	0.129	32.7	0.119	30.2	0.290	73.6
29	18.9	0.053	14.0	0.129	34.1	0.100	26.5
30	65.1	0.164	12.6	0.129	9.9	0.300	23.0

and human health, the daily average intake of Cu is 1.2 mg (WHO 1998). For decades, copper has been recognised as an essential trace metal for humans. The available data indicate that humans worldwide are at greater risk from the deficiency of Cu intake than from the excess intake (IPCS 1996). Tea infusions are not a significant dietary source of Cu. However, tea drinking apparently enhances the solubilisation and absorption of Cu from the gut, increasing the storage of the metal in the liver (Vaquero *et al.* 1994).

The Fe content in tea infusions (Table 4) decreased with time. It can be assumed that Fe is first released and then probably precipitated. In the 5 min, 60 min, and 24 h infusions, Fe content was higher in black tea than in green tea, but no significant differences were observed. Iron is an essential trace element in living organisms. The

Table 4. Total contents of Fe in tea leaves (mg/kg), concentrations of Fe in tea infusions in relation to extraction times (mg/l), and relative part of soluble Fe in tea infusions (%)

Sample	Total (mg/kg)	5 min		60 min		24 h	
		(mg/l)	(%)	(mg/l)	(%)	(mg/l)	(%)
1	143	0.038	1.33	0.062	2.17	0.037	1.29
2	303	0.105	1.73	0.066	1.09	0.051	0.84
3	227	0.073	1.61	0.063	1.39	0.048	1.06
4	309	0.069	1.12	0.084	1.36	0.056	0.91
5	405	0.100	1.23	0.253	3.12	0.257	3.17
6	368	0.069	0.94	0.112	1.52	0.040	0.54
7	103	0.051	2.48	0.057	2.77	0.043	2.09
8	314	0.142	2.26	0.146	2.32	0.180	2.87
9	136	0.075	2.76	0.096	3.53	0.052	1.91
10	202	0.049	1.21	0.068	1.68	0.047	1.16
11	209	0.084	2.01	0.044	1.05	0.057	1.36
12	162	0.131	4.04	0.077	2.38	0.132	4.07
13	391	0.059	0.75	0.075	0.96	0.077	0.98
14	137	0.038	1.39	0.025	0.91	0.026	0.95
15	199	0.069	1.73	0.086	2.16	0.075	1.88
16	200	0.083	2.08	0.083	2.08	0.054	1.35
17	436	0.142	1.63	0.024	0.28	0.054	0.62
18	140	0.049	1.75	0.059	2.11	0.056	2.00
19	225	0.099	2.20	0.077	1.71	0.074	1.64
20	342	0.088	1.29	0.034	0.50	0.037	0.54
21	306	0.059	0.96	0.068	1.11	0.062	1.01
22	233	0.075	1.61	0.059	1.27	0.044	0.94
23	227	0.099	2.18	0.075	1.65	0.063	1.39
24	378	0.062	0.82	0.066	0.87	0.055	0.73
26	202	0.053	1.31	0.041	1.01	0.045	1.11
27	182	0.074	2.03	0.062	1.70	0.054	1.48
28	210	0.037	0.88	0.035	0.83	0.048	1.14
29	170	0.045	1.32	0.037	1.09	0.046	1.35
30	523	0.055	0.53	0.054	0.52	0.097	0.93

estimates of the minimum daily requirements for Fe depends on age, sex, physical status, and iron bioavailibilty, and ranges from about 10 to 50 mg (WHO 1998). Tea infusions cannot be seen as a significant dietary source of Fe. Moreover, tea flavonoids are known to partially inhibit the absorption of iron from plant foods but not from animal sources, inhibiting the absorption of both Zn and non-haem Fe from the gut. Furthermore, this latter effect is increased with Fe, but not with Zn, by the addition of milk. If tea is not consumed until an hour after eating, the inhibitory effect is greatly reduced (Hurrell *et al.* 1999). The amount of Fe leached from the system is not high enough to constitute the iron deficiency threat even in a vegetarian, but excessive tea drinking should be avoided by people who are prone to anaemia (Kim & Miller 2005). Adding vitamin C, for example a slice of lemon,

Table 5. Total contents of Mn in tea leaves (mg/kg), concentrations of Mn in tea infusions in relation to extraction times (mg/l), and relative part of soluble Mn in tea infusions (%)

Sample	Total (mg/kg)	5 min		60 min		24 h	
		(mg/l)	(%)	(mg/l)	(%)	(mg/l)	(%)
1	694	1.46	10.5	3.04	21.9	3.33	24.0
2	1675	2.07	6.2	2.66	7.9	3.44	10.3
3	2072	7.59	18.3	5.22	12.6	10.16	24.5
4	614	0.70	5.7	1.83	14.9	2.55	20.8
5	858	1.01	5.9	3.58	20.9	5.35	31.2
6	974	0.91	4.7	2.60	13.3	2.70	13.9
7	919	2.70	14.7	3.04	16.5	4.17	22.7
8	795	1.58	9.9	2.47	15.5	2.43	15.3
9	630	1.44	11.4	1.38	11.0	3.17	25.2
10	1273	0.56	2.2	1.11	4.4	2.24	8.8
11	699	1.36	9.7	2.36	16.9	4.15	29.7
12	572	1.92	16.8	2.51	21.9	4.18	36.5
13	1183	2.53	10.7	6.15	26.0	7.62	32.2
14	535	1.15	10.7	1.99	18.6	3.94	36.8
15	1584	1.95	6.2	3.64	11.5	3.82	12.1
16	918	1.22	6.6	5.41	29.5	5.79	31.5
17	979	2.74	14.0	2.40	12.3	5.14	26.3
18	1400	2.83	10.1	5.86	20.9	6.30	22.5
19	2086	3.89	9.3	7.41	17.8	10.90	26.1
20	808	1.31	8.1	1.68	10.4	3.71	23.0
21	511	0.78	7.6	2.13	20.8	4.15	40.6
22	943	3.94	20.9	8.46	44.9	9.77	51.8
23	1267	1.97	7.8	3.48	13.7	6.16	24.3
24	1264	3.62	14.3	6.60	26.1	9.63	38.1
26	2220	2.25	5.1	6.60	14.9	14.44	32.5
27	619	0.85	6.9	1.82	14.7	2.26	18.3
28	1026	2.27	11.1	4.34	21.2	4.99	24.3
29	725	1.56	10.8	2.03	14.0	5.03	34.7
30	864	0.96	5.6	2.19	12.7	3.77	21.8

to tea serves to counteract the inhibitory effect to some extent (www.teaandcoffee.net).

The Mn content (Table 5) increased with time with a statistically significant difference. The manganese content was higher in the 5 min green tea infusions than in the 5 min black tea infusion, and statistically higher in black tea in the 60 min and 24 h infusions. Manganese was the only element found in significant dietary amounts in tea. The analysis of tea infusions before digestion showed that 1 litre contained 115% of the daily average dietary intake of Mn but < 6% of all other minerals (Powell *et al.* 1998). These authors find the mean Mn concentration in tea infusions to be 4.6 mg/l, slightly higher than our findings of 2.06 mg/l. The manganese deficiency in humans is unusual, although in the Western world, Mn intake is marginal particularly in women, and often lower than adequate (Davis *et al.* 1990; Davis & Greger 1992). Tea drinking may be

Table 6. Total contents of Zn in tea leaves (mg/kg), concentrations of Zn in tea infusions in relation to extraction times (mg/l), and relative part of soluble Zn in tea infusions (%)

Sample	Total (mg/kg)	5 min		60 min		24 h	
		(mg/l)	(%)	(mg/l)	(%)	(mg/l)	(%)
1	49.4	0.202	20.4	0.263	26.6	0.251	25.4
2	30.0	0.113	18.8	0.107	17.8	0.091	15.2
3	51.1	0.320	31.3	0.171	16.7	0.253	24.8
4	32.2	0.147	22.8	0.141	21.9	0.164	25.5
5	45.4	0.124	13.7	0.223	24.6	0.258	28.4
6	54.9	0.121	11.0	0.215	19.6	0.201	18.3
7	47.5	0.232	24.4	0.234	24.6	0.310	32.6
8	51.8	0.211	20.4	0.231	22.3	0.247	23.8
9	33.0	0.152	23.0	0.132	20.0	0.215	32.6
10	21.5	0.057	13.3	0.076	17.7	0.059	13.7
11	48.7	0.171	17.6	0.188	19.3	0.280	28.7
12	42.4	0.244	28.8	0.267	31.5	0.370	43.6
13	41.2	0.250	30.3	0.298	36.2	0.314	38.1
14	82.2	0.233	14.2	0.262	15.9	0.417	25.4
15	32.1	0.130	20.2	0.219	34.1	0.159	24.8
16	30.1	0.209	34.7	0.279	46.3	0.239	39.7
17	65.2	0.588	45.1	0.210	16.1	0.426	32.7
18	46.2	0.214	23.2	0.300	32.5	0.417	45.1
19	34.7	0.149	21.5	0.119	17.1	0.177	25.5
20	46.6	0.135	14.5	0.140	15.0	0.302	32.4
21	50.5	0.183	18.1	0.271	26.8	0.344	34.1
22	40.3	0.245	30.4	0.381	47.3	0.369	45.8
23	33.2	0.171	25.8	0.142	21.4	0.142	21.4
24	42.3	0.579	68.4	0.250	29.6	0.315	37.2
26	30.8	0.088	14.3	0.138	22.4	0.148	24.0
27	43.8	0.153	17.5	0.210	24.0	0.263	30.0
28	75.2	0.300	19.9	0.407	27.1	0.387	25.7
29	68.7	0.249	18.1	0.279	20.3	0.538	39.2
30	71.3	0.181	12.7	0.228	16.0	0.309	21.7

a major source of dietary Mn for many people. However, the speciation of Mn forms in tea infusions showed that 95% was in the form of Mn(II) and the remaining 5% as organically bound Mn suggesting poor absorption of Mn from tea infusions in gut (Özdemir & Güçer 1998).

The Zn content (Table 6) in the tea infusions increased slightly (but not statistically significantly) between 5 min and 60 min infusions, but a significant difference was seen between the 5 min or 60 min infusions and the 24 h infusions. The Zn content was higher in green tea infusion during 5 min and 60 min infusions, and significantly higher in the 24 h infusion. Zinc is an essential trace element but its content in tea infusions is low, and therefore cannot be seen as a major dietary source.

We can summarise that the total contents of metals in tea leaves differ according to the type of tea (green or black) and are probably influenced by many other factors, e.g. soil properties, location, rainfall, altitude, genetic properties of the plant, age of the leaves etc. The total content of Mn was much higher compared to the total contents of Cu, Fe, and Zn, thus resulting in a relatively high concentration of Mn in infusions. Tea infusions cannot be seen as a dietary source of essential trace metals, except for Mn.

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References

Afsana K., Shiga K., Ishizuka S., Hara H. (2004): Reducing effect of ingesting tannic acid on the absorption of iron, but not of zinc, copper and manganese by rats. Bioscience, Biotechnology and Biochemistry, **68**: 584–592.

Azam S., Hadi N., Khan N.U., Hadi S.M. (2004): Prooxidant property of green tea polyphenols epicatechin and epigallocatechin-3-gallate: implications for anticancer properties. Toxicology *in vitro*, **18**: 555–561.

Cao X., Zhao G., Yin M., Li J. (1998): Determination of ultratrace rare earth elements by inductively coupled plasma mass spectrometry with microwave digestion and AG50W-x8 cation exchange chromatography. Analyst, **123**: 1115–1119.

Davis C.D., Greger J.M. (1992): Longitudinal changes of manganese-dependent superoxide-dismutase and other indexes of manganese and iron status in women. American Journal of Clinical Nutrition, **55**: 747–752.

Davis C.D., Ney D.M., Greger J.M. (1990): Manganese, iron and lipid interactions in rats. Journal of Nutrition, **120**: 507–513.

Exley C., Korchazhkina O.V. (2001): Promotion of formation of amyloid fibrils by aluminium adenosine triphosphate (AlATP). Journal of Inorganic Biochemistry, **84**: 215–224.

Fernandez-Caceres P.L., Martin M.J., Pablos F., Gonzalez A.G. (2001): Differentiation of tea (*Camellia sinensis*) varieties and their geographical origin according to their metal content. Journal of Agricultural and Food Chemistry, **49**: 4775–4779.

Fung K.F., Zhang Z.Q., Wong J.W.C., Wong M.H. (2002): Aluminium and fluoride concentrations of three tea varieties growing at Lantua Island, Hong Kong (2002). Environmental Geochemistry and Health, **25**: 219–232.

Greenop J. (1997): The Lifestyle Food Index for South African Consumers. Demeter Publications, Gauteng, South Africa.

Hurrell R.F., Reddy M., Cook J.D. (1999): Inhibition of non-haem iron absorption in man by polyphenolic-containing beverages. British Journal of Nutrition, **81**: 289–295.

IPCS (1996): Task Group. PCS/EHC 96.28. Australia, Brisbane.

Jansen S., Watanabe T., Dessein S., Smets E., Robbrecht E.A. (2003): Comparative Study of metal levels in leaves of some Al-accumulating *Rubiaceae*. Annals of Botany, **91**: 657–663.

Jha A., Mann R.S., Balachandran R. (1996): Tea: A refreshing beverage. Indian Food Industry, **15**: 22–29.

Kim H.S., Miller D.D. (2005): Proline-rich proteins moderate the inhibitory effect of tea on iron absorption in rats. Journal of Nutrition, **135**: 532–537.

Kumar A., Nair A.G.C., Reddy A.V.R., Garg A.N. (2005): Availability of essential elements in Indian and US tea brands. Food Chemistry, **89**: 441–448.

Mader P., Száková J., Miholová D. (1998): Classical dry ashing of biological and agricultural materials. Part II. Losses of analytes due to their retention in an insoluble residue. Analusis, **26**: 121–129.

MANUGISTICS (1997): Statgraphics Plus for Windows User Manual. Manugistics, Inc., Rockville, MD.

Marcus A., Fisher A., Ree G., Hill J. (1996): Preliminary study using trace element concentrations and a chemometics approach to determine the geological origin of tea. Journal of Analytical Atomic Spectrometry, **113**: 521–525.

Matsuura H., Hokura A., Katsuki F., Itoh A., Haraguchi H. (2001): Multielement determination and speciation of major-to-trace elements in black tea leaves by ICP-AES and ICP-MS with the aid of size exclusion chromatography. Analytical Science, **17**: 391–398.

McLachlan D.R.C. (1995): Aluminium and risk for Alzheimer's disease. Environmetrics, **6**: 233–275.

Musgrave T. (2002): Empire of Plants. Cassell, New York.

Narin I., Colak H., Turkoglu O., Soylak M., Dogan M. (2004): Heavy metals in black tea samples produced in Turkey. Bulletin of Environmental Contamination and Toxicology, **72**: 844–849.

Nelson M., Poulter J. (2004): Impact of tea drinking on iron status in the UK: a review. Journal of Human Nutrition and Dietetics, **17**: 43–54.

Odegard K.E., Lund W. (1997): Multi-element speciation of tea infusion using cation-exchange separation and size-exclusion chromatography in combination with inductively coupled plasma mass spectrometry. Journal of Analytical Atomic Spectrometry, **12**: 403–408

Özdemir Y., Güçer S. (1998): Speciation of manganese in tea leaves and tea infusions. Food Chemistry, **61**: 313–317.

Powell J.J., Trevor J., Burden T.J., Thompson R.P.H. (1998): *In vitro* mineral availability from digested tea: a rich dietary source of manganese. Analyst, **133**: 1721–1724.

Saud S., Oud A.L. (2003): Heavy metal contents in tea and herb leaves. Pakistan Journal of Biological Science, **6**: 208–202.

Tascioglu S., Kok E. (1998): Temperature dependence of copper, iron, nickel and chromium transfers into various black and green tea infusions. Journal of the Science in Food and Agriculture, **76**: 200–208.

Temme E.H.M., Van Hoydonck P.G.A. (2002): Tea consumption and iron status. European Journal of Clinical Nutrition, **56**: 379–386.

Vaquero M.P., Veldhuizen M., Van Dokkum W., Van Den Hamer C.J.A, Schaafsma G. (1994): Copper bioavailability from breakfasts containing tea – influence of the addition of milk. Journal of the Science in Food and Agriculture, **64**: 475–481.

WHO (1998): Guidlines for Drinking-Water Quality, 2nd Ed., addendum to Vol. 2 Health Criteria and other Supporting Information. World Health Organisation, Geneva.

Wrobel K., Wrobel K., Urbina E.M.C. (2000): Determination of total aluminum, chromium, copper, iron, manganese, and nickel and their fractions leached to the infusions of black tea, green tea, *Hibiscus sabdariffa*, and *Ilex paraguariensis* (maté) by ETA-AAS. Biological Trace Element Research, **78**: 271–280.

Yang C.S., Hong J., Hou Z., Sang S.M. (2004): Green tea polyphenols: Antioxidative and prooxidative effects. Journal of Nutrition, **134**: 3181S–3181S.

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