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RESEARCH ARTICLE

Macroelement, trace element, and toxic metal levels in leaves and infusions of yerba mate (*Ilex paraguariensis*)

Ilaria Olivari[1] · Soraya Paz[1] · Ángel J. Gutiérrez[1] · Dailos González-Weller[2] · Arturo Hardisson[1] · Gianni Sagratini[3] · Carmen Rubio[1]

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Abstract

Mate is an infusion made from the dried leaves of yerba mate (*Ilex paraguariensis*). Yerba mate may be an important source of essential elements but could contain toxicologically relevant metals. Macroelements (Ca, Mg, Na, K), trace elements (B, Ba, Sr, V, Li, Ni, Fe, Zn, Cu, Cr, Co, Mn, Mo), and toxic metals (Al, Cd, Pb) content have been determined in 32 samples of yerba mate by ICP-OES (inductively coupled plasma—optical emission spectrometry) with the aim of determining the element content of yerba mate leaves and the influence of temperature in the extraction of these elements from the plant to the infusion, and estimating the dietary intake for each element studied. The highest element contents have been found in infusions prepared with hot distilled water (70–75 °C); the most noteworthy are K (303 mg/L), Mn (4.85 mg/L), and Al (4.52 mg/L). The consumption recommended by the producers (500 mL infusion/day) contributes significantly to the daily intake of essential elements such as Mn, Mg, and Cu. This consumption does not pose a health risk, although it is necessary to assess the risk/benefit of Ni intake from mate consumption for people with impaired renal function (500 mL/day accounts for 52.2% of the TDI).

Keywords *Ilex paraguariensis* · Yerba mate infusions · Dietary intake · Risk assessment · Toxic metals · Macroelements · Trace elements · ICP-OES

Introduction

Mate is a stimulating drink prepared with the dried leaves of *Ilex paraguariensis*, a tree belonging to the Aquifoliaceae family (Heck et al. 2008; Folch 2010) which is widely grown in southern Argentina, Brazil, Paraguay, and Uruguay (FAO/STAT 2007; Ilany et al. 2010). As a result of globalization and migratory flows, yerba mate is now found in other parts of the world and is marketed in Europe and the USA, where its consumption is increasing because of the promotion of its possible beneficial effects (Schinella et al. 2000; Lukomska et al. 2015).

The mate is traditionally prepared in a rounded metal container known as a “pot”, in which dried yerba mate leaves are placed, and hot water is poured on them (Lukomska et al. 2015). However, the preparation method of the mate has been modernized, and there are now various ways to prepare it such as the cold infusion, using water at room temperature and dipping the yerba mate repeatedly in the water (Lukomska et al. 2015).

Although yerba mate is considered nothing more than an infusion in Europe and the USA, the ancient tribes of southern America originally used yerba mate as a medicinal remedy for gastrointestinal problems and headaches, among others (Bragança et al. 2011).

Yerba mate contains a large number of active compounds, among which is chlorogenic acid which is a polyphenolic compound known for its antioxidant and anti-inflammatory activity and for reducing the risk of diabetes in people with obesity (Bastos et al. 2007; Xu et al. 2009; Bracesco et al. 2011; Ma et al. 2015; Yan et al. 2017). Chlorogenic acid is the major compound of yerba mate infusions accounting for

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✉ Carmen Rubio
crubio@ull.es

1 Department of Toxicology, University of La Laguna, 38071 La Laguna, Tenerife, Canary Islands, Spain

2 Health Inspection and Laboratory Service, Canary Health Service, S/C de Tenerife, 38006 Tenerife Canary Islands, Spain

3 School of Pharmaceutical Sciences and Health Products, University of Camerino, 62032 Camerino, Italy

42% of the total compounds (Bracesco et al. 2011). It also contains caffeine (34.4 mg/100 g), which is responsible for its energizing and stimulating effect (Dellacassa and Bandoni 2001; Heck and De Mejia 2007) and essential elements for the human body such as calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), and potassium (K) (Binaghi et al. 2011). The macrolements (Na, K, Ca, Mg) are required in high concentrations by the human organism, while the trace elements (Fe, Zn, Cu, Cr, Co, Mo, Mn) are necessary in smaller quantities and make up a part of different enzymes such as ferroxidase or cytochrome C oxidase (EFSA 2013; Rubio et al. 2017a; Rubio et al. 2018a). Macroelements and trace elements have recommended intake values.

Despite the contribution of essential elements and their beneficial effects, the consumption of yerba mate may pose risks for the health of the consumer. The absorption and accumulation of toxic and non-essential metals by this plant from the ground require risk evaluation and analysis to ensure its food safety (Copello et al. 2011).

Trace elements, such as lithium (Li), nickel (Ni), vanadium (V), boron (B), barium (Ba), or strontium (Sr), are found naturally in the environment and in food, as they are essential elements for plants and some organisms (Rubio et al. 2012; Lo Surdo 2016; Rubio et al. 2017a). These elements do not have recommended intake values. High Li intake could cause serious damage to humans as they can produce hypothyroidism, blindness, nausea and kidney damage (González-Weller et al. 2013), or Sr, whose toxicity is due to the ability of Sr to bind to phosphates, resulting in insoluble compounds that cause phosphorus deficiency (Nielsen 2004).

Toxic metals such as aluminum (Al), cadmium (Cd), or lead (Pb) are contaminants, mainly from anthropogenic sources. They are characterized for not being biodegradable and for their tendency to accumulate in the environment (Shaheen et al. 2016; Hardisson et al. 2017; Rubio et al. 2018b). These metals, even in low concentrations, can cause toxic effects.

Al is a neurotoxic agent that accumulates in the brain producing neurodegenerative diseases (Hardisson et al. 2017; Rubio et al. 2017b). Cd acts by interfering with the enzymatic reactions involving Zn, because both are divalent metals and are related (Rubio et al. 2006). It is noteworthy that the leaves of plants, such as yerba mate, are the part of the plant that accumulates the highest concentrations of Cd (Rizwan et al. 2017). Pb causes damage to the central nervous system (CNS) and nephropathies (Rubio et al. 2005; González-Weller et al. 2015; Luis et al. 2015; Rubio et al. 2018c).

For all of the above, the objectives of this study were to determine the contents of macroelements (Ca, Na, K, Mg), trace elements (Fe, Zn, Cu, Cr, Co, Mn, Mo, B, Ba, Sr, V, Li, Ni), and toxic metals (Al, Cd, Pb) in 32 samples of different yerba mate brands using ICP-OES (inductively coupled plasma–optical emission spectrometry), to establish the nutritional profile and evaluate the risk from the intake of toxic elements, as well as to evaluate the influence of the temperature of the water used to make the infusion in the transfer of elements from the dried yerba mate leaves to the infusion.

Material and methods

Samples

A total of 32 dried yerba mate (*Ilex paraguariensis*) samples from 13 different brands from Argentina, Paraguay, Brazil, and Uruguay were purchased between February 2017 and April 2017 in hypermarkets and markets in the Canary Islands (Spain). The samples were taken to the laboratory and stored in their original packaging. Table 1 shows the characteristics of each analyzed sample.

Sampling treatment

Treatment and analysis of the samples have been carried out using chemical reagents of analytical grade and distilled water of high purity from a Mili-Q purification system (Milipore, MA, USA). The glassware material and porcelain capsules (Staatlich, Germany) have been previously washed with laboratory detergent (Extran MA 02, Germany) and distilled water of high purity.

In order to study the degree of solubility of the studied elements, as well as the influence of the temperature in the preparation of the infusions, the preparation of the samples has been carried out by means of two different procedures that are described below.

Treatment of the yerba mate dry leaves

The leaves were weighed in triplicate, 10 g of each sample previously homogenized in porcelain capsules (Staatlich, Germany). They were dried in an oven (Nabertherm, Germany) at 70–80 °C for 24 h. They were then subjected to acid digestion using 2–3 mL of 65% HNO_3 (Honeybell Fluka, Germany) to eliminate organic matter, until nitric acid evaporation in a hot plate (Nabertherm, Germany).

Once the digestion of the organic matter was complete, the samples were placed in a muffle furnace (Nabertherm, Germany) for incineration. The temperature-time program used was 400 ± 20 °C/24 h, with a progressive rise in temperature of 50 °C per hour (Luis et al. 2015). Once the beige ashes were obtained, they were dissolved in 25 mL volumetric flasks with 1.5% HNO_3 solution and transferred to sterile and hermetic polyethylene containers for analysis.

Table 1 Data on the analyzed yerba mate samples

Origin	Code	No. samples	Composition	Format (kg)	Packaging
Argentina	A1	4	Prepared with leaves and twigs	½	Plastic
	A2	4		½	Plastic
	A3	4		½	Plastic
	A4	2		½	Plastic
	A5	2		½	Plastic
	A6	2		½	Plastic
	A7	2		½	Paper bag
	A8	2		1	Plastic
Paraguay	P1	2		½	Plastic
	P2	2		½	Plastic
Brazil	B1	2	Prepared only with leaves	½	Paper bag
	B2	2		1	Plastic
Uruguay	U1	2		½	Plastic

Treatment of the hot and cold yerba mate infusions

A total of 10 g of each previously homogenized sample were weighed in beakers. After which, 50 mL of distilled water was added at room temperature (25 °C) in case of the cold infusion (Lukomska et al. 2015) and at 70–75 °C in the case of the hot infusion for 10 min. The liquid was then transferred to a sterile hermetic container of 50 mL using laboratory filter paper. The process was repeated two more times dipping the yerba mate in again and collecting the filtrate in the same container up to a total volume of 100 mL. This procedure was performed in triplicate for each sample.

The next step was to take a 50 mL aliquot of each infusion and place it in porcelain crucibles (Staatlich, Germany), following the same procedure of desiccation, acid digestion, and incineration described above for samples of the dried yerba mate leaves.

Method and quality control

The determination of elements was performed using atomic emission spectrometry, using an inductively coupled plasma–optical emission spectrometer (ICP-OES) Thermo Scientific iCAP 6000 Spectrometer series model (Waltham, MA, USA). This method is the most suitable for the simultaneous determination of macroelements, trace elements, and toxic metals in food as it is a fast, reliable, sensitive, and automated technique (Hardisson et al. 2017).

The instrumental conditions were the following: gas flow (nebulizer gas flow, auxiliary gas flow) 0.5 L/min, approximate radio frequency (RF) power of 1.2 kW, flow of the sample injection of the sample to the pump of 50 rpm, and stabilization time of 0 s. The wavelengths (nm) of the analyzed elements were the following: Al (167), B (249.7), Ba (455.4), Ca (317.9), Cd (226.5), Co (228.6), Cr (267.7), Cu (327.3), Fe (259.9), K (769.9), Li (670.8), Mg (279.1), Mn (257.6), Mo (202.0), Na (589.6), Ni (231.6), Pb (220.3), Sr (407.7), V (310.2), and Zn (206.2).

The instrumental limits of quantification, calculated by analyzing 15 targets under reproducible conditions (IUPAC 1995) for each element, were the following: 0.012 mg/L (Al), 0.012 mg/L (B), 0.005 mg/L (Ba), 1.995 mg/L (Ca), 0.001 mg/L (Cd), 0.002 mg/L (Co), 0.008 mg/L (Cr), 0.012 mg/L (Cu), 0.009 mg/L (Fe), 1.884 mg/L (K), 0.013 mg/L (Li), 1.943 mg/L (Mg), 0.008 mg/L (Mn), 0.002 mg/L (Mo), 3.655 mg/L (Na), 0.003 mg/L (Ni), 0.001 mg/L (Pb), 0.003 mg/L (Sr), 0.005 mg/L (V), and 0.007 mg/L (Zn).

The precision and accuracy of the method were checked by a strict quality control, using certified reference materials (CRM) of matrices similar to the samples under study, which had been subjected to the same treatment and analysis as the samples. The quality control was based on the percentage of recovery of each analyzed element (Table 2). The materials chosen were SRM 1515 apple leaves and SRM 1548a typical diet, both from the National Institute of Standards and Technology (NIST). The recovery percentages obtained were greater than 97%. In addition, a statistical analysis was carried out concluding that there were no significant differences between the concentration found and the one certified by the manufacturer.

Statistical analysis

The statistical analysis of the samples was conducted to determine the existence or not of significant differences ($p < 0.05$)

Table 2 Concentration (mean ± SD, *n* = 3) of the reference materials and recovery study (%) of the analyzed elements

Material	Metal	Concentration (mg/kg)	Obtained concentration (mg/kg)	Recovery (%)
SRM 1515 apple leaves	Na	24.4 ± 1.2	24.3 ± 0.8	99.6
	K	1.61 ± 0.02	1.57 ± 0.04	97.8
	Ca	1.526 ± 0.02	1.570 ± 0.05	102.3
	Mg	0.271 ± 0.01	0.260 ± 0.03	98.1
	Fe	80.0 ± 0.0	79.6 ± 0.2	99.5
	Mn	54.0 ± 3.0	54.8 ± 6.2	101.5
	Cu	5.64 ± 0.24	5.58 ± 0.32	98.9
	Zn	12.5 ± 0.3	12.7 ± 0.5	101.9
	Cr	0.30 ± 0.00	0.29 ± 0.03	97.8
	Mo	0.094 ± 0.01	0.09 ± 0.02	99.4
	Co	0.09 ± 0.00	0.09 ± 0.03	101.5
	B	27 ± 2	27 ± 1.5	99.9
	Sr	25 ± 2	24.6 ± 4	98.3
	Ni	0.91 ± 0.12	0.92 ± 0.18	100.6
	Al	286 ± 9	285.1 ± 26	99.7
	Pb	0.470 ± 0.024	0.470 ± 0.04	100.3
	Cd	0.014 ± 0.00	0.014 ± 0.003	99.3
SRM 1548a typical diet	Na	8132 ± 942	8001.9 ± 476	98.4
	K	6970 ± 125	6858.5 ± 318	98.4
	Ca	1967 ± 113	1961.1 ± 158	99.7
	Mg	580 ± 26.7	580 ± 26.7	97.7
	Fe	35.3 ± 3.77	35.6 ± 5.17	101.3
	Mn	5.75 ± 0.17	5.71 ± 0.36	99.3
	Cu	2.32 ± 0.16	2.34 ± 0.29	100.7
	Zn	24.6 ± 1.79	24.3 ± 1.32	98.7
	Mo	0.26 ± 0.02	0.26 ± 0.05	98.6
	B	4.16 ± 0.04	4.23 ± 0.02	101.8
	Ba	1.10 ± 0.10	1.13 ± 0.09	102.5
	Sr	2.93 ± 0.10	2.91 ± 0.25	99.2
	Ni	0.37 ± 0.02	0.38 ± 0.04	102.3
	V	0.26 ± 0.03	0.26 ± 0.06	100.6
	Al	72.4 ± 1.52	71.2 ± 3.23	98.3
	Pb	0.044 ± 0.000	0.044 ± 0.013	98.9
	Cd	0.035 ± 0.015	0.036 ± 0.006	102.2
Standard addition method	Li	0.2 ± 0.02	0.19 ± 0.03	95.0

between the two preparation methods of the infusions, as well as with the dried yerba mate leaves. This analysis was performed using the IBM Statistics SPSS 22.0 for Mac™ software.

Firstly, the distribution of the data was studied by the Kolmogorov-Smirnov and Shapiro-Wilk tests (Rubio et al. 2017b). Given that the data did not follow a normal distribution, nonparametric tests such as the Kruskal-Wallis test and the Mann-Whitney U test were used (Gutiérrez et al. 2008; Jaudenes et al. 2018).

Results and discussion

Element contents in the analyzed yerba mate samples

Table 3 shows the mean concentrations (mg/kg dry weight) and standard deviations (SD) of the elements in yerba mate leaves. As regards the macroelements, the most noteworthy concentration was found in Ca (3450 ± 554 mg/kg dry weight), followed by K > Mg > Na. The highest concentrations were found in yerba mate samples identified as P1, from

Table 3 Mean concentration (mg/kg) and standard deviation of the analyzed elements in the yerba mate leaf samples

Code	Ca	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Zn
A1	4293 ± 482	< LOQ	0.41 ± 0.08	3.73 ± 1.37	9.52 ± 5.30	2890 ± 178	3237 ± 431	48.1 ± 6.67	< LOQ	536 ± 104	28.0 ± 9.57
A2	3521 ± 429		0.22 ± 0.07	4.10 ± 1.29	9.11 ± 2.62	2627 ± 89.8	2398 ± 448	47.0 ± 11.0		566 ± 161	29.9 ± 9.51
A3	3811 ± 246		0.36 ± 0.02	3.83 ± 1.47	11.4 ± 7.80	2670 ± 83.0	2578 ± 305	47.0 ± 10.9		675 ± 120	24.7 ± 4.43
A4	3421 ± 251		0.43 ± 0.06	8.18 ± 0.82	36.4 ± 18.1	3484 ± 144	1958 ± 195	114 ± 14.1		906 ± 93.7	50.9 ± 4.31
A5	5211 ± 230		37.7 ± 17.1	< LOQ	2467 ± 256	3642 ± 171	3257 ± 223	9636 ± 1748	0.62 ± 0.30	983 ± 123	600 ± 27.2
A6	5595 ± 596		39.6 ± 3.91	< LOQ	4328 ± 1174	3878 ± 321	3722 ± 423	13,370 ± 1012	0.56 ± 0.24	1073 ± 104	661 ± 61.9
A7	2992 ± 361		0.52 ± 0.07	6.93 ± 0.70	54.7 ± 3.78	3416 ± 279	2102 ± 151	99.6 ± 18.2	< LOQ	795 ± 46.0	49.8 ± 3.83
A8	2721 ± 118		0.53 ± 0.06	5.72 ± 0.15	33.2 ± 10.9	2918 ± 102	2283 ± 127	89.1 ± 19.2		1101 ± 253	42.1 ± 1.71
B1	2654 ± 158		0.17 ± 0.02	5.83 ± 0.39	19.6 ± 3.59	4114 ± 230	2125 ± 167	74.0 ± 8.99	0.04 ± 0.01	1295 ± 238	33.2 ± 0.92
B2	3148 ± 246		0.16 ± 0.02	3.01 ± 1.47	10.3 ± 7.80	2383 ± 83.0	2438 ± 305	41.5 ± 10.9	< LOQ	614 ± 120	9.70 ± 4.43
P1	6166 ± 482		38.1 ± 3.78	< LOQ	8068 ± 2681	4070 ± 220	3831 ± 284	11,771 ± 2766	1.17 ± 0.35	1245 ± 130	734 ± 28.5
P2	4646 ± 471		31.6 ± 6.53	< LOQ	6422 ± 1866	3620 ± 323	3065 ± 417	7587 ± 2527	0.62 ± 0.36	719 ± 96.7	664 ± 113
U1	3208 ± 250		0.47 ± 0.07	9.17 ± 1.65	45.7 ± 17.8	3593 ± 323	2427 ± 228	114 ± 18.0	< LOQ	1023 ± 162	38.8 ± 5.68
Mean ± SD	3450 ± 554	< LOQ	0.35*±0.13	5.17 ± 2.07	21.6*±16.5	3023 ± 517	2480 ± 416	66.4*±30.2	0.60 ± 0.40	774 ± 264	32.5*±11.9

Code	Al	B	Ba	Cd	Li	Ni	Pb	Sr	V
A1	48.8 ± 7.17	22.4 ± 1.41	2.84 ± 0.61	0.11 ± 0.04	2.33 ± 0.58	1.27 ± 0.22	0.20 ± 0.01	< LOQ	< LOQ
A2	50.2 ± 8.33	16.8 ± 2.10	4.55 ± 1.37	0.13 ± 0.04	3.10 ± 1.49	1.29 ± 0.39	0.15 ± 0.04		
A3	50.9 ± 8.62	24.1 ± 0.84	4.81 ± 0.21	0.10 ± 0.04	2.05 ± 0.80	1.38 ± 0.15	0.17 ± 0.00		0.09 ± 0.02
A4	138 ± 10.6	22.6 ± 2.45	24.6 ± 4.10	0.35 ± 0.01	4.42 ± 0.12	1.55 ± 0.21	0.37 ± 0.05	21.3 ± 3.43	0.14 ± 0.02
A5	9632 ± 507	231 ± 25.8	7044 ± 676	2558 ± 4418	262 ± 56.2	79.6 ± 1.90	12.4 ± 0.57	4942 ± 263	5.74 ± 0.52
A6	9723 ± 330	234 ± 20.4	7635 ± 1334	8.95 ± 1.16	154 ± 42.4	88.6 ± 7.25	12.1 ± 0.87	4689 ± 476	6.18 ± 0.22
A7	158 ± 8.49	22.6 ± 2.45	19.2 ± 2.92	0.24 ± 0.02	8.57 ± 2.63	1.98 ± 0.19	0.34 ± 0.03	16.6 ± 1.52	0.15 ± 0.06
A8	163 ± 2.70	20.6 ± 0.50	18.6 ± 4.43	0.21 ± 0.01	4.10 ± 2.63	2.19 ± 0.20	0.34 ± 0.01	19.3 ± 0.55	0.09 ± 0.00
B1	108 ± 11.1	16.0 ± 0.44	18.1 ± 4.56	0.44 ± 0.02	4.06 ± 1.88	0.71 ± 0.03	1.64 ± 2.22	17.1 ± 0.73	< LOQ
B2	56.9 ± 8.62	16.1 ± 0.84	3.04 ± 0.21	0.10 ± 0.04	1.68 ± 0.80	0.83 ± 0.15	0.23 ± 0.00	< LOQ	0.07 ± 0.02
P1	10,215 ± 450	294 ± 20.9	9125 ± 1005	2210 ± 3813	235 ± 72.8	79.3 ± 1.11	14.5 ± 1.33	7112 ± 550	6.44 ± 0.05
P2	11,987 ± 805	206 ± 16.9	6560 ± 2457	8.57 ± 1.51	299 ± 181	69.0 ± 15.9	12.8 ± 1.64	6496 ± 645	5.79 ± 0.40
U1	162 ± 5.85	19.2 ± 2.07	17.6 ± 5.05	0.33 ± 0.03	5.06 ± 1.23	1.60 ± 0.14	0.39 ± 0.08	27.5 ± 12.7	0.09 ± 0.01
Mean ± sd	90.4*±50.9	20.3*±3.21	10.4*±8.29	0.19 ± 0.12	3.57*±1.94	1.39*±0.44	0.36*±0.41	20.4*±4.40	3.06 ± 3.19

LOQ limit of quantification

*The concentrations of the samples identified as P1, A6, A5, and P2 have been discarded

Paraguay, with levels of 6166 ± 482 mg Ca/kg d.w., 3831 ± 284 mg Mg/kg d.w., and 1245 ± 130 mg Na/kg d.w. A study conducted by Pozebon et al. (2015) found in yerba mate leaf from Paraguay, a concentration of Ca (6947 ± 710 mg/kg) and Mg (4597 ± 287 mg/kg) similar to the concentration, was found in the present study.

The essential trace element concentrations that stand out were in Mn (66.4 ± 30.2 mg/kg d.w.) and Zn (32.5 ± 11.9 mg/kg d.w.), followed by Fe > Cu > Mo > Cr. High concentrations of Fe, Zn, Cr, and Mn were found in samples P1, A6, A5, and P2, which indicate some type of contamination. These samples, originating from the northeast of Argentina and southern Paraguay, come from areas near the delta of the Paraná River. The Paraná River is one of the longest in South America, which, due to anthropogenic activities, is highly polluted with concentrations of Cd, Pb, Fe, and Mn exceeding the limits recommended by the legislation of these countries (Cataldo et al. 2001; Puig et al. 2016). Therefore, these high concentrations may be due to the proximity of the Paraná River to where these plants grow.

As for the non-essential elements, the concentration levels of Sr (20.4 ± 4.40 mg/kg d.w.) and B (20.3 ± 3.21 mg/kg d.w.) are noteworthy; the rest of the non-essential elements follow the sequence of concentration of Ba> Li > V > Ni. Again, samples P1, A6, A5, and P2 had high concentrations of B, Ba, Li, Ni, and Mn that could be explained taking into account the possible contamination of the Paraná River abovementioned.

A previous study conducted by Wróbel et al. (2000) shows levels of Mn (2223 ± 110 mg/kg), Fe (166 ± 19 mg/kg), Cr (2.24 ± 0.15 mg/kg), Cu (11.1 ± 0.15 mg/kg), and Ni (4.6 ± 0.2 mg/kg), which are lower than levels found in the present study. However, the referenced study was conducted in 2000, so the levels of these elements could vary among the years.

Of the toxic metals, Al was found in the highest concentration with an average level of 90.4 ± 50.9 mg/kg d.w. The Al levels found by Pozebon et al. (2015) in yerba mate leaf from Paraguay (384 ± 63 mg Al/kg) and Argentina (347 ± 60 mg Al/kg) are higher than the levels recorded in the present study. The Al concentration in the environment has increased due to both anthropogenic activities such as bauxite extraction or aluminum industries, as well as natural soil erosion and acidification activities (Sjögren et al. 2007; Hardisson et al. 2017). The concentrations found in the samples mentioned above (P1, A6, A5, P2) for toxic elements are again quite high compared with the rest of the samples.

Tables 4 and 5 show the concentrations (mg/L) and standard deviations found in the hot and cold prepared infusions. The highest concentrations of macroelements were found in the hot prepared infusions, in which the K level (303 ± 42.2 mg/L) is worth mentioning, followed by Mg > Na > Ca. The results obtained by Olivier et al. (2012) shown a level of K of 133.4 mg/L (33.35 mg/250 mL); this value is lower than the obtained in the present study. The statistical analysis revealed significant differences ($p < 0.05$) in Ca and Mg levels between both types of infusions.

Regarding the essential trace elements, the highest concentrations were found in the hot prepared infusions, the most notable of which were the contents of Mn (4.85 ± 1.36 mg/L) and Zn (2.24 ± 0.41 mg/L). The remaining microelements followed the sequence Cu > Fe > Cr > Mo. Except for V, the concentration of non-essential metals is higher in the hot prepared infusions, especially B (1.47 ± 0.23 mg/L) and Ba (0.46 ± 0.10 mg/L), followed by Li > Sr > Ni > V. Once again, the recorded levels of toxic metals were higher in hot prepared infusions, with Al having the highest average concentration of 4.52 ± 0.98 mg/L. A study conducted by Gomes da Costa et al. (2009) shows Al levels in mate tea between 2.23 and 2.50 mg/L.

The statistical study showed that the Mo and Ni levels were significantly different between both infusions. Cd and Al levels were statistically significant between the two types of infusions (hot and cold infusion). Temperature influences on the extraction of the elements from the leaf of yerba mate to the infusion.

The study conducted by Bragança et al. (2011), in which the content of some trace elements and toxic metals was determined in infusions of different brands of yerba mate from Brazil prepared with hot water reported mean concentrations of: Cu (0.03–0.06 mg/L), Zn (0.41–1.0 mg/L), Al (0.32–1.7 mg/L), Fe (0.12–0.23 mg/L), and Mn (2.3–7.0 mg/L). The above concentrations are lower than those obtained in the present study, both for hot and cold prepared infusions, except for Mn, whose mean concentration was lower than that found in the abovementioned study. The differences found may be due to multiple factors such as the soil, mode of preparation, season, and origin (Barbosa et al. 2015).

Extraction percentage of the studied elements in infusions

Taking into account the average concentrations of each element obtained in the samples of dried leaves of yerba mate and those obtained in the infusions prepared both with hot and cold water, the percentages of extraction of both infusions were calculated as follows:

$$\text{Extraction}(\%) = \frac{\text{Element concentration in yerba mate infusion}}{\text{Element concentration in dried yerba mate leaves}} \cdot 100$$

The percentages of extraction of the studied elements in the hot prepared infusions were the following: Al (5.0%), B (7.2%), Ba (4.4%), Ca (1.9%), Cd (2.8%), Cr (7.0%), Cu (11.1%), Fe (1.3%), K (9.4%), Li (10.3%), Mg (7.1%), Mn (7.3%), Mo (5.4%), Na (8.0%), Ni (13.5%), Pb (3.5%), Sr (1.8%), V (7.9%), and Zn (6.9%),whereas the percentages of extraction for the cold prepared infusions were the following:

Table 4 Concentration (mg/L) and standard deviation of analyzed elements in the yerba mate hot infusion samples

Code	Ca	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Zn
A1	85.5 ± 20.7	< LOQ	0.03 ± 0.01	0.45 ± 0.10	0.22 ± 0.12	292 ± 97.9	190 ± 50.3	5.29 ± 1.34	< LOQ	65.5 ± 35.7	2.19 ± 0.90
A2	64.8 ± 4.88		0.02 ± 0.00	0.59 ± 0.10	0.33 ± 0.09	340 ± 28.5	176 ± 16.2	2.69 ± 0.75		81.0 ± 13.4	1.78 ± 0.05
A3	50.9 ± 2.69		0.02 ± 0.00	0.50 ± 0.06	0.18 ± 0.09	341 ± 6.14	172 ± 7.02	3.05 ± 1.23		49.1 ± 15.7	2.11 ± 0.10
A4	66.7 ± 4.54		0.02 ± 0.00	0.47 ± 0.12	0.24 ± 0.09	342 ± 17.4	196 ± 13.0	4.31 ± 1.77		76.4 ± 38.3	3.09 ± 0.11
A5	70.7 ± 6.25		0.03 ± 0.00	< LOQ	0.34 ± 0.09	317 ± 5.41	184 ± 11.8	7.35 ± 0.65	0.002 ± 0.000	60.4 ± 11.3	2.74 ± 0.17
A6	54.9 ± 6.74		0.03 ± 0.00		0.25 ± 0.08	216 ± 17.8	140 ± 18.3	4.53 ± 1.49	0.001 ± 0.000	46.5 ± 13.1	2.32 ± 0.14
A7	55.7 ± 2.02		0.03 ± 0.00	0.53 ± 0.11	0.21 ± 0.03	313 ± 12.6	197 ± 12.3	5.26 ± 1.12	< LOQ	79.5 ± 27.7	2.42 ± 0.03
A8	64.5 ± 5.41		0.03 ± 0.00	0.83 ± 0.15	0.25 ± 0.08	304 ± 7.42	249 ± 11.5	7.28 ± 1.09		40.4 ± 5.26	1.89 ± 0.12
B1	58.5 ± 8.05		0.01 ± 0.00	0.52 ± 0.14	0.43 ± 0.12	305 ± 12.0	197 ± 19.1	5.02 ± 0.78	0.001 ± 0.000	82.5 ± 32.5	1.71 ± 0.18
B2	84.2 ± 1.76		0.02 ± 0.01	0.77 ± 0.07	0.22 ± 0.09	337 ± 11.9	234 ± 5.57	5.24 ± 1.26	< LOQ	79.0 ± 35.5	1.86 ± 0.18
P1	52.7 ± 2.75		0.03 ± 0.00	< LOQ	0.33 ± 0.20	261 ± 12.4	173 ± 20.7	4.58 ± 0.64	0.001 ± 0.000	45.5 ± 12.1	2.69 ± 0.18
P2	43.0 ± 2.87		0.03 ± 0.01		0.25 ± 0.17	234 ± 28.4	138 ± 16.1	3.95 ± 1.44	0.002 ± 0.000	41.3 ± 23.4	2.00 ± 0.31
U1	91.5 ± 1.32		0.02 ± 0.00	0.80 ± 0.03	0.26 ± 0.03	339 ± 2.29	269 ± 9.17	4.45 ± 1.35	< LOQ	114 ± 4.04	2.32 ± 0.07
Mean ± SD	64.9 ± 14.7	< LOQ	0.03 ± 0.01	0.58 ± 0.14	0.27 ± 0.07	303 ± 42.2	193 ± 38.4	4.85 ± 1.36	0.001 ± 0.000	66.2 ± 21.7	2.24 ± 0.41
Code	Al	B	Ba	Cd	Li	Ni	Pb	Sr	V		
A1	3.36 ± 0.90	1.14 ± 0.05	0.35 ± 0.06	0.003 ± 0.001	0.42 ± 0.12	0.17 ± 0.01	< LOQ	< LOQ	< LOQ		
A2	4.36 ± 0.60	1.01 ± 0.08	0.40 ± 0.04	0.002 ± 0.000	0.45 ± 0.05	0.16 ± 0.01					
A3	3.93 ± 0.61	1.15 ± 0.07	0.35 ± 0.04	0.003 ± 0.000	0.44 ± 0.10	0.20 ± 0.01			0.01 ± 0.00		
A4	4.87 ± 0.08	1.23 ± 0.07	0.59 ± 0.05	0.004 ± 0.000	0.49 ± 0.07	0.25 ± 0.01	0.01 ± 0.00	0.35 ± 0.03	0.01 ± 0.00		
A5	4.09 ± 0.84	1.33 ± 0.09	0.37 ± 0.09	0.004 ± 0.001	0.33 ± 0.04	0.22 ± 0.00	0.01 ± 0.00	0.32 ± 0.02	0.01 ± 0.00		
A6	3.15 ± 0.20	1.14 ± 0.09	0.27 ± 0.05	0.004 ± 0.000	0.27 ± 0.07	0.12 ± 0.02	0.01 ± 0.00	0.28 ± 0.13	0.01 ± 0.00		
A7	5.65 ± 0.39	1.67 ± 0.83	0.34 ± 0.07	0.004 ± 0.001	0.52 ± 0.14	0.17 ± 0.09	0.02 ± 0.00	0.32 ± 0.09	0.01 ± 0.00		
A8	3.34 ± 0.93	0.77 ± 0.03	0.24 ± 0.03	0.004 ± 0.000	0.26 ± 0.02	0.09 ± 0.00	0.01 ± 0.00	0.28 ± 0.02	0.01 ± 0.00		
B1	2.86 ± 0.17	1.02 ± 0.11	0.25 ± 0.02	0.003 ± 0.000	0.15 ± 0.05	0.18 ± 0.01	0.01 ± 0.00	0.36 ± 0.01	0.02 ± 0.00		
B2	5.04 ± 0.41	1.45 ± 0.09	0.31 ± 0.02	0.004 ± 0.000	0.30 ± 0.06	0.17 ± 0.01	0.01 ± 0.00	< LOQ	0.01 ± 0.00		
P1	2.24 ± 0.50	0.97 ± 0.37	0.26 ± 0.08	0.003 ± 0.001	0.15 ± 0.07	0.13 ± 0.06	0.01 ± 0.00	0.21 ± 0.07	0.01 ± 0.01		
P2	3.20 ± 0.65	1.24 ± 0.07	0.34 ± 0.02	0.004 ± 0.000	0.21 ± 0.06	0.15 ± 0.00	0.01 ± 0.00	0.34 ± 0.10	0.01 ± 0.00		
U1	4.65 ± 0.48	1.10 ± 0.04	0.45 ± 0.02	0.005 ± 0.000	0.60 ± 0.06	0.18 ± 0.01	0.02 ± 0.00	0.43 ± 0.04	0.01 ± 0.00		
Mean ± SD	3.90 ± 0.98	1.17 ± 0.23	0.35 ± 0.10	0.004 ± 0.001	0.35 ± 0.14	0.17 ± 0.04	0.01 ± 0.00	0.32 ± 0.05	0.01 ± 0.00		

LOQ limit of quantification

Table 5 Concentration (mg/L) and standard deviation of analyzed elements in the yerba mate cold infusion samples

Code	Ca	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Zn
A1	60.2 ± 2.38	< LOQ	0.02 ± 0.00	0.38 ± 0.15	0.09 ± 0.07	312 ± 16.3	163 ± 9.24	2.50 ± 1.16	< LOQ	44.9 ± 8.75	1.59 ± 0.38
A2	48.6 ± 3.61		0.02 ± 0.00	0.42 ± 0.08	0.26 ± 0.10	342 ± 20.8	154 ± 13.0	3.77 ± 0.88		56.8 ± 4.13	1.45 ± 0.13
A3	50.6 ± 3.60		0.02 ± 0.00	0.51 ± 0.09	0.32 ± 0.17	337 ± 16.0	158 ± 10.3	4.04 ± 0.85		53.2 ± 9.57	1.82 ± 0.10
A4	61.0 ± 6.08		0.03 ± 0.00	0.54 ± 0.07	0.24 ± 0.07	297 ± 9.07	230 ± 13.1	4.09 ± 0.67		54.5 ± 4.50	1.88 ± 0.13
A5	63.7 ± 2.75		0.02 ± 0.00	< LOQ	0.20 ± 0.13	316 ± 5.68	176 ± 7.81	4.32 ± 0.57		48.9 ± 0.58	2.56 ± 0.14
A6	63.5 ± 21.7		0.02 ± 0.00		0.20 ± 0.05	259 ± 4.93	149 ± 13.9	2.22 ± 0.37		88.2 ± 33.0	2.02 ± 0.12
A7	43.5 ± 14.0		0.03 ± 0.01	0.49 ± 0.23	0.45 ± 0.31	256 ± 83.4	141 ± 74.9	4.80 ± 0.95		52.9 ± 25.5	2.79 ± 1.40
A8	51.7 ± 2.91		0.01 ± 0.00	0.55 ± 0.09	0.16 ± 0.06	360 ± 5.50	190 ± 5.06	3.36 ± 0.44		48.3 ± 3.37	1.77 ± 0.11
B1	70.5 ± 6.38		0.01 ± 0.00	0.52 ± 0.02	0.11 ± 0.04	261 ± 16.0	206 ± 23.0	2.09 ± 0.50		45.6 ± 1.71	1.41 ± 0.06
B2	49.9 ± 5.87		0.02 ± 0.00	0.58 ± 0.05	0.35 ± 0.05	304 ± 13.5	166 ± 12.9	5.62 ± 0.58		39.9 ± 10.4	2.80 ± 0.13
P1	42.3 ± 15.8		0.02 ± 0.01	< LOQ	0.17 ± 0.02	237 ± 56.3	141 ± 56.1	3.37 ± 1.12		40.2 ± 17.8	1.43 ± 0.64
P2	114 ± 60.1		0.02 ± 0.00		0.20 ± 0.03	254 ± 6.33	171 ± 1.04	3.25 ± 1.44		101 ± 18.8	2.14 ± 0.04
U1	78.7 ± 3.69		0.02 ± 0.00	0.70 ± 0.18	0.25 ± 0.09	334 ± 6.25	235 ± 14.6	4.01 ± 0.41		70.3 ± 9.29	2.10 ± 0.16
Mean ± SD	61.4 ± 19.0	< LOQ	0.02 ± 0.01	0.50 ± 0.10	0.23 ± 0.10	298 ± 40.3	175 ± 31.4	3.65 ± 1.01	< LOQ	57.3 ± 18.5	1.98 ± 0.49

Code	Al	B	Ba	Cd	Li	Ni	Pb	Sr	V
A1	4.40 ± 0.92	1.42 ± 0.35	0.62 ± 0.13	0.003 ± 0.001	0.27 ± 0.09	0.18 ± 0.05	0.01 ± 0.00	< LOQ	< LOQ
A2	5.01 ± 0.24	1.31 ± 0.13	0.57 ± 0.05	0.003 ± 0.000	0.65 ± 0.00	0.18 ± 0.02	0.01 ± 0.00		
A3	3.34 ± 0.76	1.44 ± 0.06	0.35 ± 0.04	0.003 ± 0.000	0.37 ± 0.11	0.19 ± 0.01	0.01 ± 0.00		0.01 ± 0.00
A4	3.74 ± 0.61	1.59 ± 0.08	0.35 ± 0.03	0.006 ± 0.000	0.32 ± 0.07	0.16 ± 0.00	0.01 ± 0.00	0.31 ± 0.02	0.01 ± 0.00
A5	5.28 ± 0.39	1.74 ± 0.09	0.42 ± 0.03	0.005 ± 0.001	0.52 ± 0.00	0.23 ± 0.01	0.02 ± 0.00	0.33 ± 0.01	0.01 ± 0.00
A6	4.42 ± 0.16	1.26 ± 0.18	0.32 ± 0.02	0.005 ± 0.001	0.39 ± 0.00	0.18 ± 0.02	0.01 ± 0.00	0.25 ± 0.02	0.01 ± 0.00
A7	5.27 ± 0.84	1.74 ± 0.11	0.49 ± 0.02	0.005 ± 0.000	0.16 ± 0.11	0.24 ± 0.01	0.01 ± 0.00	0.34 ± 0.01	0.01 ± 0.00
A8	5.02 ± 0.32	1.61 ± 0.06	0.80 ± 0.03	0.004 ± 0.000	0.39 ± 0.00	0.28 ± 0.03	0.01 ± 0.00	0.40 ± 0.02	0.01 ± 0.00
B1	4.38 ± 0.63	0.83 ± 0.02	0.33 ± 0.09	0.005 ± 0.001	0.20 ± 0.14	0.07 ± 0.01	0.02 ± 0.00	0.27 ± 0.04	0.01 ± 0.00
B2	5.12 ± 0.60	1.54 ± 0.02	0.48 ± 0.10	0.004 ± 0.000	0.46 ± 0.04	0.26 ± 0.00	0.01 ± 0.00	< LOQ	0.01 ± 0.00
P1	4.42 ± 0.95	1.89 ± 0.20	0.39 ± 0.02	0.004 ± 0.000	0.27 ± 0.08	0.16 ± 0.01	0.01 ± 0.00	0.31 ± 0.02	0.01 ± 0.00
P2	3.57 ± 1.46	1.25 ± 0.06	0.33 ± 0.03	0.004 ± 0.001	0.23 ± 0.01	0.13 ± 0.02	0.01 ± 0.00	0.26 ± 0.02	0.01 ± 0.00
U1	4.77 ± 0.18	1.47 ± 0.04	0.53 ± 0.03	0.020 ± 0.026	0.54 ± 0.09	0.18 ± 0.01	0.01 ± 0.00	0.46 ± 0.03	0.01 ± 0.00
Mean ± SD	4.52 ± 0.65	1.47 ± 0.27	0.46 ± 0.14	0.005 ± 0.005	0.37 ± 0.14	0.19 ± 0.05	0.01 ± 0.00	0.36 ± 0.10	0.01 ± 0.00

LOQ limit of quantification

Al (4.3%), B (5.8%), Ba (3.3%), Ca (1.8%), Cd (1.8%), Cr (5.5%), Cu (9.6%), Fe (1.1%), K (9.3%), Li (9.9%), Mg (6.4%), Mn (5.5%), Na (6.9%), Ni (12.2%), Pb (3.3%), Sr (1.6%), V (9.8%), and Zn (6.1%).

In view of the results obtained, it is confirmed that the infusions prepared with hot water have higher percentages of extraction due to a greater transfer of these facilitated by the higher temperature (Jokic et al. 2010). It is noteworthy that, in the case of vanadium, the greatest transfer was found in cold prepared infusions. However, the transfer of the studied elements from the dry leaves of yerba mate to the infusions is, in all cases, less than 20%, which may be due to the presence of proteins, fats, fibers, and compounds such as caffeine or theobromine which can decrease the solubility of metals (Barbosa et al. 2015).

A study conducted by Sanz and Isasa (1991) concluded that the extraction of elements from the leaves of yerba mate to the infusion does not show the same behavior. Thus, for example, these authors found a higher Ca content in the yerba mate leaves (around 80–90%) than in the infusion, due to the low solubility of this element in water, while other elements with greater solubility will be better extracted in aqueous medium.

Dietary intake assessment

The evaluation of the dietary intake of the studied elements was performed based on the consumption per ration suggested by the manufacturers (500 mL infusion per day), the mean concentrations obtained in both infusions and the recommended and maximum values that are described below (Table 6) (Table 7).

The recommended daily requirements of the essential elements studied for adults are provided by the European Food Safety Authority (EFSA 2019); on the other hand, the values of tolerable daily intake (TDI) and/or tolerable weekly intake (TWI), as well as the upper limit (UL) are provided by different international organizations.

The consumption of 500 mL of hot prepared yerba mate infusion would mainly contribute to the Mn intake whose percentage of contribution to the established adequate intake (AI) of 3 mg Mn/day (adults) is representing the 81%. The contribution of Mn from the infusions of yerba mate is remarkable. This essential element is necessary because it is part of numerous enzymes such as peptidases, phosphatases, arginase, and glucosyl transferases (Blanco 2006), and is necessary in the metabolism of amino acids, cholesterol, and carbohydrates (IOM 2001).

Mg contribution is noteworthy because its percentage of estimated contribution is 27.6% for men and of 32.2% for women of the AI set at 350 and 300 mg Mg/day for men and women, respectively. Mg is a cofactor necessary in more than 300 enzymatic reactions into the human organism (Blanco 2006).

Yerba mate hot infusions contribute to the daily requirement of Cu with 22.3% of the AI for women of 1.3 mg Cu/day (EFSA 2019). Cu is necessary because it is part of multiple

Table 6 Estimated daily intake and percentages of contribution to the AI of the studied elements

Essential elements	Guideline values (EFSA 2019)	Yerba mate prepared with hot water				Yerba mate prepared with cold water			
		C. mean \(mg/L)	EDI (mg/day)[a]	% AI		C. mean (mg/L)	EDI (mg/day)[a]	% AI	
				Women	Men			Women	Men
Ca	750 mg/day	64.9	32.5	4.33	4.33	61.4	30.7	4.10	4.10
Cu	1.3 mg/day (women), 1.6 mg/day (men)	0.58	0.29	22.3	18.1	0.50	0.25	19.2	15.6
Fe	7 mg/day (women), 6 mg/day (men)	0.27	0.14	2.00	2.33	0.23	0.12	1.71	2.00
K	3500 mg/day	303	152	4.34	4.34	298	149	4.26	4.26
Mg	300 mg/day (women), 350 mg/day (men)	193	96.5	32.2	27.6	175	87.5	29.2	25.0
Mn	3 mg/day	4.85	2.43	81.0	81.0	3.65	1.83	61.0	61.0
Mo	65 μg/day	0.001	0.0005	0.77	0.77	-	-	-	-
Na	2000 mg/day	66.2	33.1	1.66	1.66	57.3	28.7	1.44	1.44
Zn[b]	6.2 mg/day (women), 7.5 mg/day (men)	2.24	1.12	18.1	14.9	1.98	0.99	16.0	13.2
Zn[c]	7.6 mg/day (women), 9.3 mg/day (men)	2.24	1.12	14.7	12.0	1.98	0.99	13.0	10.6
Zn[d]	8.9 mg/day (women), 11 mg/day (men)	2.24	1.12	12.6	10.2	1.98	0.99	11.1	9.00
Zn[e]	10.2 mg/day (women), 12.7 mg/day (men)	2.24	1.12	11.0	8.82	1.98	0.99	9.71	7.80

[a] Taking a mean daily consumption of 500 mL of yerba mate

[b] Considering a phytate level intake of 300 mg/day

[c] Considering a phytate level intake of 600 mg/day

[d] Considering a phytate level intake of 900 mg/day

[e] Considering a phytate level intake of 1200 mg/day

Table 7 Estimated daily intake and percentages of contribution to the TWI, TDI, and/or UL of the studied elements

Non-essential and toxic elements	Guideline values		Yerba mate prepared with hot water				Yerba mate prepared with cold water			
			C. mean (mg/L)	EDI (mg/day)*	% TWI**, TDI**, or UL		C. mean (mg/L)	EDI (mg/day)*	% TWI**, TDI**, or UL	
					Men	Women			Men	Women
Al	1 mg/kg body weight/week (EFSA 2011)	TWI	4.52	2.26	23.1	23.1	3.90	1.95	19.9	19.9
B	17–20 mg/day (IOM 2001)	UL	1.47	0.74	4.35	4.35	1.17	0.59	3.47	3.47
Ba	0.2 mg/kg bw/day (SCHER 2012)	TDI	0.46	0.23	16.8	16.8	0.35	0.18	13.1	13.1
Cd	2.5 µg/kg bw/week (EFSA 2011)	TWI	0.005	0.003	12.3	12.3	0.004	0.002	8.18	8.18
Ni	2.8 µg/kg bw/day (EFSA 2015)	TDI	0.19	0.10	52.2	52.2	0.17	0.09	46.9	46.9
Pb	0.5 µg/kg bw/day (AESAN 2012)		0.01	0.005	14.6	14.6	0.01	0.005	14.6	14.6
Sr	0.13 mg/kg bw/day (WHO 2010)		0.36	0.18	2.02	2.02	0.32	0.16	1.80	1.80
V	1.8 mg/day (IOM 2001)	UL	0.01	0.05	2.78	2.78	0.01	0.005	0.28	0.28

*Taking a mean daily consumption of 500 mL of yerba mate

**Taking the mean weight of an adult as 68.48 kg (AESAN 2006)

enzymes, and participates in the metabolism of Fe, in the regulation of gene expression, and in mitochondrial function (IOM 2001; Blanco 2006).

The values found in the cold yerba mate infusion for the analyzed elements are lower than the values found in the hot infusions. The hot infusions contribute greatly to cover the daily requirements of some elements.

Considering the TDI of Ni of 2.8 µg Ni/kg bw/day (EFSA 2015), the contribution percentage of Ni is 52.2%, in other words, slightly higher than half the maximum value. Individuals with hypersensitivity to children with kidney problems are susceptible to damage due to Ni intake (IOM 2001). The rest of contribution percentages are below 25% of their respective maximum admissible values.

The consumption of 500 mL/day of yerba mate infusion does not pose a health risk for human. However, it is necessary to monitor the levels of certain elements in the yerba mate in order to detect possible contamination.

Conclusions

The content of toxic metals and non-essential elements found in the dried leaves of some yerba mate brands (P1, A6, P2, and A5) from areas close to each other indicates that these crops could be affected by some type of environmental contamination that along with the capacity of absorption and accumulation of elements of this plant can explain such high concentrations of them. However, the study of the element content in the prepared infusions shows that, although there is contamination, the transfer of these elements from the dried leaves to the infusions is, in general, low and is slightly higher in the case of the infusions prepared with hot water. Likewise, the evaluation of dietary intake from the consumption of 500 mL of yerba mate infusion reveals that this infusion is a notable source of essential elements such as Mn, Mg, and Cu. While the dietary intake of toxic metals and non-essential elements, although not a risk to health, the maximum allowable intake of Ni may be exceeded in cases of high levels of consumption. It is necessary to assess the level of certain elements in yerba mate in order to detect any contamination.

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