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Trace Elements in Different Brands of Yerba Mate Tea

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Abstract Yerba mate (*Ilex paraguariensis*), a widely consumed beverage in South America, contains various biochemically active substances, among them are several minerals. This paper reports on the results of a survey of trace elements in the yerba mate infusions. Three different commercially available trademarks of *I. paraguariensis* were evaluated, simulating the popular mode of preparation. Atomic absorption analyses for cadmium, lead, copper, zinc, aluminum, iron, chromium, manganese, molybdenum, and silver were performed using a graphite furnace. The levels ranged from 0.03 to 0.06 mg/L for copper, from 0.41 to 1.0 mg/L for zinc, from 0.32 to 1.7 mg/L for aluminum, from 0.12 to 0.23 mg/L for iron, from 2.3 to 7.0 mg/L for manganese, and from 0.01 to 0.03 mg/L for silver. The levels of chromium did not exceed 0.005 mg/L, while molybdenum, cadmium, and lead were lower than <0.01 mg/L. Metal content in mate tea infusions depends on a number of factors, some of which are controllable and others not, but the differences among various sources are admissible. Trace elements in mate plants seem to be weakly bounded to the substrate. The concentration of biometals does not exceed the limits accepted by Brazilian and international legislation when available.

Keywords *Ilex paraguariensis* · Yerba mate · Mate tea · Trace elements · Biometals

Introduction

The determination of trace elements content in different teas has been a subject of numerous studies. Most of them were carried out in order to characterize specific chemical compounds, existing in the plant *Ilex paraguariensis*, a native perennial tree belonging to Aquifoliaceae family [1–3]. This tree grows naturally, but presently, it is cultivated in Brazil, Paraguay, Uruguay, and Argentina. It is to be noted that the term "herb" may be confusing, since it popularly refers to a part of a plant valued for its medicinal, savory, and

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aromatic qualities. Its leaves, after being dried and minced, are used to prepare a traditional tea, which is widely consumed as a tonic and stimulant beverage in South America.

Historically, consuming it is a part of an important ritual signifying trust and communion. The act of drinking mate is more than just that, it is often used as a symbol of sharing a good chat with a partner, meeting new people, or just for meditation at the end of the day.

The plant has been popular for centuries, primarily adopted from the local Indian inhabitants, the Guaranies, populating a region that comprises Paraguay, Southern Brazil, Uruguay, and North Eastern Argentine. It is known under different names: "yerba mate" or "té del Paraguay" in Paraguay itself, "erva mate" or "chimarrão" in Brazil, and simply "mate" in Argentina and Uruguay. When cold water is used for preparations, mostly in summer, this beverage is called "tereré." In areas with very hot climate, including the State of Mato Grosso do Sul, Brazil, this drink is excellent as a refreshment being a low-calorie, non-alcoholic quencher, appreciated, in everyday life, by a vast majority of population.

Used as a popular remedy, it happens to heal a number of ailments such as headache, stomachache, and diarrhea, simply by adding the plant to the water [4, 5]. In fact, *I. paraguariensis* properties have been extensively reviewed, confirming its health benefits. The available bibliography reports that mate tea shows hepatoprotective [5], hypocholesterolemic, diuretic [6], and antioxidant [7, 8] effects. It has also been referred as stimulant for the central nervous and cardiovascular systems [9]. Some studies have suggested its potential in the management of obesity [10–12].

In vitro experiments showed its benefits as a protector of DNA oxidation and low-density lipoprotein lipoperoxidation [13]. Numerous biochemically active substances that promote well-being have been identified in yerba mate. Among them are some polyphenols, xanthines, alkaloids, flavonoids, vitamins, and minerals [14, 15]. The literature points out that some agronomic variables, like age and light intensity, exert a remarkable influence on the assortment and concentrations of volatile and semi-volatile chemical compounds in mate leaves [16].

As to mineral composition, several studies have been carried out to determine the content of bioactive metals in *I. paraguariensis* and its infusions [17–19], including a vast review on the matter [2]. These metals can be either toxic like lead or benefic like zinc. In the latter case, biological effects are also extremely important as the antioxidant properties of the tea may be due also to their presence.

Apparently, all the reviewed data might be sufficient to bring a whole picture of trace elements in yerba mate. Nevertheless, as happens, a single and uniform approach of data collection is lacking, even the list of the trace metals covered in the articles is not the same. Naturally, such a situation does not allow the realization of a proper comparison between the available sources. Besides, in most papers, the origin of the plants samples and basic soil conditions are not sufficiently documented. It is to bear in mind that the extent to which plants take up metals depends not on genetic factors exclusively but on the binding of trace elements to soils constituents, as well as on the macro- and microenvironmental conditions in which they grow [20]. The growing popularity of mate tea in recent years on the bases of its health benefits requires additional information and periodic control of the findings.

Doubtless, all these factors cannot be taken into account simultaneously, so the only solution may be to place a limitation on the extent of research and to focus exclusively on the beverage itself. In this case, one should consider tea characteristics for a given region where yerba mate is extensively consumed, simulating the process of making ready for use by local consumers.

This paper reports on the results of a survey of some trace elements in the yerba mate produced and consumed in the State of Mato Grosso do Sul, Brazil, in particular, in the state capital, Campo Grande.

Methods

In the industrialization of yerba mate are used leaves, petioles, and twigs with an approximate composition of 30% branches and 70% leaves. Three different commercially available trademarks of yerba mate were evaluated. Dry plant was purchased from a department store in Campo Grande, Mato Grosso do Sul, proceeding from national producers: Santo Antônio, Tereré,[1] and Chimarrão.

The samples consisted of commercial *I. paraguariensis* without any conservative products or sugar. For the purpose of determination of the trace elements, an infusion, simulating the popular beverage, was prepared. To start with, around 50 ml of deionized water was added to 120 g of mate herb. After 5 min, the mixture was gently swirled and filtered, and deionized water was newly added. This operation was repeated ten times, adding up the extracts. For the infusions of Santo Antônio and Tereré brands, the water was previously cooled to 10°C. The same procedure was performed for Chimarrão brand, this time using hot water, previously heated to 80°C. Thus, three samples of the beverage were available to be analyzed. It seemed reasonable to expect that in teas prepared from Santo Antônio and Tereré varieties of mate, the extraction with hot water would produce higher values of minerals.

The main reagent used for sample digestion was 65% nitric acid purchased from Merck (Suprapure). Working standard solutions used for the construction of calibrating curves were from Merck. All glassware were of Pyrex® glass; prior to analysis, it was soaked for 24 h in 35% HNO_3.

Atomic absorption analyses for cadmium, lead, copper, zinc, aluminum, iron, chromium, manganese, molybdenum and silver were performed with a graphite furnace FS 240 Varian spectrometer. Sample mineralization was carried out using wet digestion technique. After separation of leaves, 4.0 ml of 65% HNO_3 was added to 6.0 g of the infusion and the volume completed with 2.0 ml of ultrapure water. Actually, we are not the ones that maintain a proposal of using vanadium pentoxide as an additive to nitric acid [21] because, unfortunately, commercially available V_2O_5 even of the best purity (99.3%) still contains up to 0.15% of iron, 0.1% of manganese, and 0.07% of chromium, as well as other heavy metals [22].

Next, the mixture was placed in a Pyrex® tube and heated on a bath with boiling water. When NO_2 fumes stopped to emerge, the solutions were cooled down to room temperature and then diluted to a final volume of 25 ml and analyzed by injection into the machine. All samples were analyzed in triplicate.

Results and Discussion

The results of analytical determinations are given in Table 1. Before considering the concentrations of individual trace elements, one can state that the absorption of metals ions from solution is not higher for the samples heated 80°C than expected previously. The main

[1] Meaning *Tereré* as a brand.

Table 1 Trace elements in the yerba mate (*I. paraguariensis*) infusions produced and consumed in the State of Mato Grosso do Sul, Brazil

Brands	Trace elements concentrations (mg/L±SD)									
	Cd	Pb	Cu	Zn	Al	Fe	Cr	Mn	Mo	Ag
Santo Antônio	<0.01±0.0003	<0.01±0.0002	0.03±0.0003	0.41±0.0007	0.32±0.0001	0.12±0.0003	<0.005±0.0002	2.3±0.0003	<0.01±0.0002	0.03±0.0002
Tereré	<0.01±0.0002	<0.01±0.0003	0.04±0.0001	1.0±0.0001	0.37±0.0001	0.19±0.0002	<0.005±0.0001	3.1±0.0005	< 0.01±0.0002	0.03±0.0001
Chimarrão	<0.01±0.0003	<0.01±0.0002	0.06±0.0002	0.8±0.0001	1.7±0.0001	0.23±0.0002	<0.005±0.0001	7.0±0.0003	< 0.01±0.0001	0.01±0.0002

SD standard deviation

reason in this case may be a weak bonding of the metals to the substrate allowing their lixiviation in conditions of low temperature.

According to the Table 1, the levels of toxic metals cadmium and lead in all samples are very low (0.01 mg/L or less). Vulcano et al. (2008), analyzing metals in infusion of mate tea in metropolitan area of Belo Horizonte, Brazil, obtained the values of 1.4±1.0 μg/L for Cd and 1.8±0.1 μg/L for Pb [23]. Nevertheless, the current Brazilian legislation does not establish any maximum level of these elements for teas [24]. Only for juices, the content of lead is given as 0.3 mg/kg. So, one can see that the concentrations observed in the present study are well below those of Belo Horizonte region for teas and never reach those permitted by legislation for other popular beverages.

Copper levels for the three teas studied are in the range of 0.03±0.0003–0.06±0.0002 mg/L. In the available Brazilian literature, copper content in mate tea infusion is reported as 11.0 mg/L [17]. Similar value, 9.0 mg/L, was found in Guanajuato, Mexico for the same drink [18]. The Brazilian directive does not set maximum limits for copper in non-alcoholic beverages. It is to be noted that the values observed in the present study are almost 100 times lower than those earlier reported. Such striking differences may be due to usage of copper compounds (oxychloride, Bordeaux mixture) widely employed as fungicides components for the control of mate black-spot disease [25].

Zinc contents observed in the present study were 0.41±0.0007–1.0±0.0001 mg/L, while the zinc concentrations reported for the samples from the State of Rio Grande do Sul, Brazil are extremely higher, that is 59.0 mg/L [17]. As has been observed in a work dealing with different teas originated from China, climate and agricultural practices, including soil, water, and fertilizers, can be of great influence on the zinc composition of samples [26]. Anyway, more data are needed to confirm these differences.

Our data for aluminum contents in yerba mate vary in the range 0.32±0.0001–1.7±0.0001 mg/L. The only data available on this subject in Brazil are the studies carried out in the State of Paraná and in the neighboring State of Rio Grande do Sul, Brazil, where aluminum content was determined in infusions of roasted yerba mate samples. According to these authors, Al concentration in Parana varied from 0.5 to 1.67 mg/L [17, 19], which is exactly the same value as determined in the present work. However, in Rio Grande do Sul, aluminum content in the infusions was incredibly high, e.g., 445 mg/L. On the other hand, in Mexico, a study has also reported rather high values for aluminum concentration, 78.6 mg/L [18].

The aluminum concentration in mate infusion may depend on the levels of organic chelating species such as chlorogenic acids, tannins, and other phenolic compounds present in the dry yerba mate, which may be modified or degraded during roasting step [27]. Nevertheless, the mode of bonding does not reveal the source of metal ions, which has to do mainly with agronomic variables. Yerba mate naturally occurs on soils with high level of Al^{3+}, generally with a medium to clay texture and does not grow well in shallow soils [28]. Aluminum ion is easily solubilized from soils at low pH in the form of basic salts. That is, to our knowledge, the main reason of aluminum accumulation in certain areas, giving, as a result, elevated values of its concentration in the plant, which according to recent data may be considered as aluminum-fixing shrub [29]. The other possibility is air contamination in the industrialized State of Rio Grande do Sul.

The iron content observed in the present study was 0.12±0.0003–0.23±0.0002 mg/L, which was lower than 203 mg/L detected in Rio Grande do Sul State [17], while Wróbel et al. (2002) report intermediate value of 5.5 mg/L [18]. In these circumstances, it is reasonable to attribute large amounts detected in Rio Grande do Sul either to air pollution or to high phosphorus content in the environment, since the concentrations of both elements are closely correlated [29].

The chromium content determined in this study was very low, less than 0.005± 0.0002 mg/L, despite the fact that in Mato Grosso do Sul, chromium compounds in the form of Cr^{3+} and Cr^{6+} have been discharged as liquid effluents from several tanneries [30]. According to available literature, chromium has been detected only in mate infusions from Guanajuato, Mexico in larger amounts, around 1.1 mg/L [18].

Manganese content determined in this study was between 2.3±0.0003 and 7.0± 0.0003 mg/L, which is much lower than in Rio Grande do Sul State, Brazil, that is 932 mg/ L. This value is comparable to the data reported by Mexican researchers, 1,069 mg/L [18], and to the content of this element in mate tea leaves, 1,315 ppm. On the other hand, Paraguayan investigators determined manganese content in leaves as 32.8–107 mg/100 g [31]. So, the difference can be tentatively explained by the influence of agronomic variables, as well as by the factors affecting manganese release from soil minerals, mainly from its dioxide MnO_2.

In our study, the levels of molybdenum concentrations in all samples were extremely low (<0.01±0.0001 mg/L). So far, no data are available in the literature. It is not unusual since direct evidence for active plant uptake is lacking.

The silver contents in this study vary from 0.01±0.0002 to 0.03±0.0002 mg/L. Eventual sources of contamination have been ruled out, but this possibility cannot be completely excluded. No published data on silver content in beverages are available so far. Nevertheless, several authors have demonstrated the ability of some fungal and bacterial species to accumulate silver without any apparent adverse effect [32, 33]. Various workers have also confirmed the uptake of silver by higher plants. Biologically available silver exists predominantly in the form of coordination compounds or as absorbed species [34, 35].

This investigation was not intended to clarify the nutritional capacity of mate teas. So, the values obtained here for biometals levels indicate exclusively the exposure to these minerals, concretely in Mato Grosso do Sul, Brazil, no assumptions made as to their real absorption or bioavailability.

Conclusions

1. Metal content in mate teas infusion depends on a number of factors, some of which are controllable and others not, so large differences among various sources are admissible.
2. The concentrations of biometals in mate teas of Mato Grosso do Sul, Brazil do not exceed the limits accepted by Brazilian and International legislation when available.
3. The extraction of trace elements from mate is not proportional to heat of treatment, probably because of the weak bounding of metal ions to the substrate.

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