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Minerals content of Paraguayan yerba mate (*Ilex paraguariensis*, S.H.)

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SUMMARY.- Minerals content (Fe, Ca, Mn, Mg, Na, K, Zn and Cu) of the leaves of Paraguayan yerba mate (*Ilex paraguariensis*, S.H.) as well as of commercial products has been determined by atomic absorption spectrophotometry. Considerable amounts of iron and calcium and remarkably high content of magnesium and potassium have been found both in the leaves and in the commercial products. Highly significant difference between the Fe content of the leaves and that of the commercial products has been found. Also, highly significant difference has been found between the Fe and Ca content of the higher quality-greater sale reputed commercial products and that of the lower quality-smaller sale reputed ones. Seasonal and soil linked variations are also presented. The nutritional and quality control significance of these findings for the MERCOSUR (Southern South America Economical Gommunity) are discussed.
KEY WORDS: Nutrition, minerals, yerba mate, Paraguayan tea, MERCOSUR.

RESUMEN.- Contenido de minerales en yerba mate paraguaya (*Ilex paraguariensis* S. H.). Se ha determinado el contenido de minerales en hojas de yerba mate (*Ilex paraguariensis*, S.H.) cultivadas en el Paraguay, así como de ocho marcas de yerba comercial paraguaya, por espectrofotometría de absorción atómica. Se ha encontrado un alto contenido de Fe, Ca, K y Mg, tanto en las hojas como en las muestras de yerba comercial. Se ha encontrado una concentración de Fe significativamente más alta en el polvo de yerba comercial con relación al polvo de hojas, lo cual sugiere fuerte contaminación durante el procesamiento. Se expone el posible impacto nutricional del consumo de la yerba en la región. Se presentan además las variaciones relacionadas con las estaciones y el tipo de suelo. Se discute la importancia de estos hallazgos con relación a las propiedades nutricionales y el control de calidad para el Mercado Común del Sur (MERCOSUR).
PALABRAS CLAVES: Nutrición, minerales, yerba mate, mate, MERCOSUR.

INTRODUCTION

Early in this century, the apparently extraordinary stimulating and physical endurance enhancement properties of a herb consumed as cold (maceration) and hot (infusion) water preparations by country workmen in Paraguay and neighboring regions of Argentina, Brasil and Uruguay, raised the interest and curiosity of Eu pean scientists. The herb was named Ca a (currently, yerba mate or Paraguayan tea) by the natives of the country. The undernourished workers showed an incredible labor and physical work capacity in the plantations and farms where they began work at sunrise and ended at sunset. The active constituent of the herb, initially named mateína (1,2), was proved to be identical to caffeine (1,3,4,5,6,7). Later, in more recent times (4,5,7), traces of theophylline and theobromine were also found (0.002 and 0.05 % respectively). However, the stimulant caffeine was not sufficient to explain the workers extraordinary muscular efficiency. Consequently, a considerable amount of scientific work has been done searching for the yerba mate chemical composition which has thus far, identified several organic compounds (3). Nevertheless, there are no updated information on the mineral content of the Paraguayan yerba mate except for the preliminary results reported at the Primera Jornada de Investigación Científica y Tecnológica de la Universidad Nacional de Asunción, Paraguay (7), which showed a remarkable high Ca and Fe content. A study on comercial yerba mate samples of unidentified sources was carried on at the Universidad Complutense de Madrid, Spain that also shows high Ca and Fe content as well as of other minerals (8). The confirmation of the high Ca, Fe, Mg and K concentrations and of its ready water extraction would turn yerba mate from a simple stimulant into minerals rich food. This would allow us to recommend its consumption even as a coffee substitute with the obvious nutritional, economical and, possibly, health advantages (9,10,11,12) for the countries that produce it such as Paraguay. In addition, these findings would support the hypothesis (R. Vera García) which holds that the massive consumption of the infusion and maceration of this product would explain the anthropometric measures of the Paraguayan population which, apparently, do not agree with the traditional Ca defficiency in the Paraguayan diet. The determination of minerals content could also permit establishing more effective

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quality control regulations for commercial yerba mate. For all of these reasons this work has been undertaken.

MATERIALS AND METHODS

Equipment: Shimadzu AA-630-12 atomic absorption spectrophotometer with individual cathode lamps specific for each mineral, air-acetilene flame system, air compressor with air filter, water deionizer-distillator and a Moulinex grinder were used.

Chemicals: They, were all from Merck or Riedel-de Haen (Germany).

Sampling: The work was carried on in two stages: First Stage (1991) and Second Stage (1992). In the First Stage (1991), two samplings of yerba mate leaves were done (August 13,1991 and October 12, 1991), three samples each of different sites, being taken, in duplicates (2 bags) in each sampling. The samples were collected from yerba mate plantations in the area of Bella Vistav, Itapua, southern part of Paraguay, close to the Argentinian border. There are about 20 cm level difference between sample collection sites which were identified as A, B and C (height of A > B > C). In the Second Stage (1992), other two samplings of yerba mate leaves were done (May 25, 1992 and August 28, 1992) at the same sites of the First Stage, three samples being taken with the same identification A, B and C based on the same criteria. Samples of the plant were also collected for its botanical identification. As to the commercial yerba mate, in the First Stagev two 1 kg packages of four different brands reputed as of higher quality and greater sale were collected (November 29, 1991) on the selling spots in Asunción and neighboring towns. In the Second Stage, samples of commercial yerba mate were collected (April 10, 1992) within the same area and the same amounts as the First Stage but, this time four brands reputed as of lower quality and smaller sale.

Sample processing: Yerba mate leaves washed clean with distilled-deionized water and wiped dry with absorbent tissue were put to dry at about 22°C in a controlled atmosphere (air conditioner and deshumidifier) once aliquots of fresh leaves had been separated for water content determination. Dry leaves were ground in a Moulinex grinder and, aliquots of the powder were taken for minerals and moisture determinations. As to the commercial yerba mate, of every one kilogram pack, two aliquots were taken of the powder obtained after passing it through a N° 16 sieve for minerals and moisture determinations. Contents of sticks (large and small) were determined by a two sieve system (N°8 and 16) separation which was completed manually.

Minerals determination: The methods of A.O.A.C. and Osborne (13,14), modified, were followed. For yerba mate leaves samples, duplicate aliquots of the dried leaves were ashed in a muffle furnace at 500° C for 2 hours plus another

TABLE 1

Minerals content in yerba mate leaves in mg/100g (dry basis) First stage (1991) First sampling

Sample	Fe	Ca	Na	K	Mg	Mn	Zn	Cu
Ala	11.2	2,608	43.6	2,050	422	72.8	4.07	1.25
Alb	8.13	632	39.3	1,800	426	76.1	4.22	1.36
A2a	9.75	583	44.9	1.830	408	70.0	3.52	1.07
A2b	9.76	609	33.9	2,030	426	71.6	3.96	1.01
Bla	10.8	592	57.5	1,800	430	49.1	3.36	1.07
Blb	8.93	536	53.5	2,110	382	44.7	2.11	1.18
B2a	8.37	493	32.3	2,150	346	41.6	1.67	1.14
B2b	7.83	528	48.7	2,150	369	43.1	1.89	1.13
Cla	8.41	503	34.5	1,800	382	43.3	1.46	1.29
C2c	7.91	534	45.7	1,740	388	51.0	1.47	1.36
C2a	8.43	527	58.7	2,010	383	48.6	1.57	1.18
C2b	9.73	539	49.6	1,800	395	49.2	1.68	1.13
Mean	9.11	557	45.2	1,940	396	55.1	2.58	1.18
SD	1.08	157.3	8.56	151	25.2	12.8	1.09	0.11

TABLE 2

Minerals content in yerba mate leaves in mg/100g (dry basis) First stage (1991) Second sampling

Sample	Fe	Ca	Na	K	Mg	Mn	Zn	Cu
Ala	8.69	550	62.0	2,130	340	60.4	3.89	1.17
Alb	8.64	568	49.1	2,280	346	63.3	3.89	1.23
A2a	7.65	627	41.9	2,120	360	70.1	4.66	0.93
A2b	8.23	642	72.6	2,070	360	68.9	4.57	0.99
Bla	12.7	752	35.8	1,930	412	93.7	4.83	1.00
Blb	13.7	794	58.2	1,830	419	72.5	4.68	1.12
B2a	12.9	562	36.5	1,950	369	71.2	2.96	1.06
B2b	11.8	575	51.1	1,850	359	96.8	3.19	1.17
Cla	12.5	817	33.0	2,240	461	99.6	7.04	1.00
C2c	12.5	804	61.4	1,990	477	119	6.87	1.00
C2a	13.0	1,961	42.7	2,030	499	121	6.44	0.94
C2b	12.1	1,014	55.3	2,020	514	119	5.47	0.94
Mean	11.4	806	50.0	2,040	410	88.0	4.87	1.05
SD	1.93	153	11.8	134.2	60.7	22.0	1.29	0.09

Moisture content of the two samplings (Mean):59.8%

TABLE 3

Minerals content in yerba mate leaves in mg/100g (dry basis) Second stage (1991) First sampling

Sample	Fe	Ca	Na	K	Mg	Mn	Zn	Cu
Ala	13.0	748	84.6	2,630	620	32.8	8.31	2.46
Alb	13.5	751	77.8	2,830	631	34.3	8.60	1.97
A2a	11.3	745	643	2,590	650	107.0	9.62	2.21
A2b	11.8	740	65.6	2,650	644	107.0	9.62	2.05
Bla	13.3	785	74.8	2,240	607	35.3	15.2	2.22
Blb	13.8	800	68.4	2,500	571	35.7	14.8	1.93
B2a	10.5	864	56.8	2,520	690	94.4	11.6	2.24
B2b	12.3	887	54.0	2,600	690	98.7	11.8	2.53
Cla	13.5	782	89.1	2,220	756	77,7	6.93	2.76
C2c	13.8	848	75.3	2.360	712	78.3	6.93	3.01
C2a	14.6	760	87.3	2.340	704	79.2	10.3	2.51
C2b	12.8	762	72.7	2,430	720	84.3	10.3	2.31
Mean	12.8	789	72.6	2,490	666	72.0	10.3	2.35
SD	1.13	48.8	10.8	174	51.9	28.2	2.56	0.30

hour after nitric acid treatment. The ash was treated with 10 ml of hydrochloric acid (1+ 1), filtered into a 100 ml volumetric flask and taken to volume with deionized-distilled water after addition of La to a final concentration of 1%. The mineral concentrations were determined by means of an atomic absorption spectrophotometer with calibration curves prepared for every mineral. For commercial yerba mate the procedure was the same as with the leaves, two aliquots in duplicates being taken of the powder as such.

Moisture determination: Two 5 g aliquots of either fresh yerba leaves cleaned of dust, and of commercial yerba, in duplicates, were taken to the oven at 105° C, during 4 h.

DISCUSSION

The data statistical analysis was done by the Analysis of Variance, the Student's t test and the Standard Error where applicable. Regarding the main objective of this work, the most remarkable point observed in the results is the high content of Fe, Ca, K and Mg in the leaves of yerba mate (12.1, 739, 2, 500 and 531 mg per 100 g, on the dry basis, respectively) as well as in the commercial preparations (48.9, 858, 1,750 and 499 mg per 100 g, on the dry basis, respectively). Although the content of all the minerals in the leaves of natural yerba mate plants matches that of the commercial ones, it is surprising the, apparently ilogical, highly significant ($P < 0.001$) higher Fe content of the commercial products. This suggests an Fe contamination during processing, particularly, in the toasting step, when the leaves are in contact with this metal at high temperature. A highly significant ($P < 0,01$) difference between the mean values of the Fe and Ca of the yerba leaves of the two harvesting periods (1991-1992) has been found, which may be due to environmental factors. No significant difference has been found between the mean values of Fe and Ca of the leaves of yerba mate of sites A, B and C (analysis of variance). However, significant difference ($P < 0.05$) has been found between the Fe mean values of samples of sites A and C which could be attributed to the lower ground level of site C. Highly significant differences ($P < 0.001$ and $P < 0.01$ respectively) have been found between the mean values of Fe and Ca of the higher quality-greater sale products and those of lower quality-smaller sale ones Should this proved to be a constant, it could constitute one more parameter for quality control, principally of Fe which, again, appears with a significant difference even higher than Ca.

CONCLUSIONS

The yerba mate, widely consumed in the MERCOSUR area (Argentina, Brazil. Paraguay and Uruguay) owing to its extraordinary content of Fe, Ca, K and Mg, appears, very likely, as an important source of these minerals in the diet of the urban and rural populations of Paraguay and, mainly in the rural population of the other cited countries considering

TABLE 4

Minerals content in yerba mate leaves in mg/100g (dry basis) Second stage (1992) Second sampling

Sample	Fe	Ca	Na	K	Mg	Mn	Zn	Cu
A1a	11.2	866	37.1	3,420	623	62.2	5.85	1.43
A1b	12.1	855	32.8	3,390	586	57.3	6.5	1.39
A2a	14.4	854	34.6	3,360	606	89.0	11.7	1.26
A2b	14.5	852	36.5	3,440	587	85.2	11.6	1.50
B1a	16.5	694	43.3	3,370	532	98.0	6.67	1.38
B1b	16.4	716	41.7	3,600	548	101.0	5.72	1.49
B2a	11.9	747	63.2	3,820	620	91.2	11.1	1.10
B2b	11.9	755	58.8	3,620	639	91.3	10.3	1.20
C1a	21.9	1,110	33.5	3,520	782	85.2	12.3	1.38
C2c	21.3	1,110	36.3	3,230	792	85.3	12.7	1.38
C2a	13.7	1,070	57.5	4,030	745	92.8	16.9	1.45
C2b	13.8	1.030	61.5	3,720	757	91.1	16.9	1.54
Mean	15.0	888	44.8	3.540	651	85.8	10.7	1.38
SD	3.38	147	11.4	217	88.6	12.6	3.74	0.12

Moisture content of the two samplings (Mean):64.0%

TABLE 5

Minerals content in commercial yerba mate leaves in mg/100g (dry basis) First stage (1991)

Sample	Fe	Ca	Na	K	Mg	Mn	Zn	Cu
A1a	32.7	748	60.1	2,560	426	101	3.85	1.59
A1b	27.7	739	46.2	2,310	433	98.6	3.51	1.72
A2a	30.2	759	49.7	2,060	429	98.6	3.62	1.18
A2b	23.2	835	41.2	2,050	40	95.6	3.51	1.14
B1a	36.9	736	47.5	1,510	406	119.0	2.03	1.22
B1b	42.9	829	46.7	1,400	429	124	2.04	1,65
B2a	32.9	785	42.8	1,490	409	124	1.85	1.53
B2b	40.6	724	55.6	2,160	413	116	2.00	1.46
C1a	20.6	817	40.1	1,800	441	70.8	3.81	1.39
C2c	19.0	849	49.8	1,760	425	68.5	3.56	1.32
C2a	17.9	844	526	1,770	464	73.4	3.96	1.21
C2b	20.6	818	55.7	1,680	423	73.2	3.79	1.41
D1a	18.8	751	45.6	155	456	71.3	3.13	1.25
D2b	22.4	810	44.0	1,500	438	70.4	3.34	1.32
D2a	23.4	772	48.6	1.580	413	71.6	3.26	1.21
D2b	18.5	765	52.8	1,680	439	69.8	3.02	1.28
Mean	26.8	786	48.7	1,800	431	90.4	3.14	1.37
SD	18.5	40.9	5.42	323	16.2	20.9	0.71	0.17

Sticks content: one determination for every 1 kg sample. Mean of every brand A1 y A2:14.2% B1 y B2:20,8% C1 y C2:17.6% D1 y D2:19.2% / Mean of all brands: 17.9 / Moisture content (Mean of all brands) 7.37%

TABLE 6

Minerals content in commercial yerba mate leaves in mg/100g (dry basis) Second stage (1992)

Sample	Fe	Ca	Na	K	Mg	Mn	Zn	Cu
A1a	52.4	1,240	25.8	1,740	597	101.0	11.5	1.80
A1b	50.0	1,150	24.9	1,520	604	101.0	11.5	1.96
A2a	58.0	1,070	24.1	1,940	594	85.6	12.4	1.65
A2b	57.1	1.270	23.4	1,860	592	91.8	12.6	1.80
B1a	79.0	1,020	34.1	1,510	488	12.0	7.52	1.62
B1b	71.2	1,000	30.9	1,600	494	113	7.57	1.67
B2a	70.1	946	22.8	1,650	509	110	7.55	1.51
B2b	70.3	803	22.6	1,770	543	121	7.57	1.45
C1a	48.6	931	27.8	1,740	614	91.2	15.1	1.47
C2c	47.5	924	28.6	2,030	640	92.0	15.0	1.29
C2a	39.8	942	28.4	1,120	620	89.0	15.0	1.10
C2b	40.0	933	34.7	1,980	634	90.1	15.6	1.14
D1a	101.0	651	26.1	1,690	548	111	4.77	1.43
D2b	103.0	618	32.5	1,610	540	105	4.48	1.45
D2a	104.0	662	30.0	1,770	547	113	4.99	1.97
D2b	112.0	704	33.8	1,600	519	109	4.96	1.50
Mean	69..0	929	28.2	1,700	568	103	9.88	1.55
SD	23.5	195	4.02	212	48.6	11.3	4.00	0.24

Sticks content: one determination for every 1 kg sample. Mean of every brand A1 + A2:20.4% B1 + B2:18% C1+C2:22.7% D1 + D2:17.8% / Mean of all brands: 19.7% Moisture content (Mean of all brands) 8.89%

the massive consumption either as a maceration (tereré) or as an infusion or tea. The bioavailability of the minerals remains to be determined. It should be remembered, here, the high of caffeine and tannic acid in this herb.(3,5,6,7). It has been reported (8) maceration and infusion extractions of 12 and 14 %, respectively, for Fe and Ca. Should these values proved to be true, the amount of these minerals ingested would still be considerable on account of the large volume consumed per day either as a maceration (a sort of cold tea) or as an infusion (a sort of hot tea), mainly in Paraguay and Uruguay. Moreover, this would be supporting the hypothesis (R. Vera García) that the consumption of yerba mate, due to its high Ca content, would be explaining the anthropometric measurements of the Paraguayan population which do not seem to match the traditional Ca defficiency in the diet of those people. These findings could also explain the extraordinary capacity for physical work of the undemourished plantation workmen in the rural areas of Paraguay observed by European and regional scientists which was attributed by the former to the consumption of a «mysterious» herb called «Ca á» (yerba mate), phenomenon not explainable sufficiently by its caffeine content (1,5). The difference encountered between the two groups of commercial yerba mate in terms of their Fe and Ca content reinforces the possibility of taking the minerals content as another parameter for quality control of this product.

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