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Aluminum Contents in Dry Leaves and Infusions of Commercial Black and Green Tea Leaves: Effects of Sucrose and Ascorbic Acid Added to Infusions

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ABSTRACT

Tea consumption has increased due to its beneficial effects. Results from a lab study on the effect of sucrose (5 *g per cup*, 150 *mL*) *and/or ascorbic acid* (2 *mL per cup*, 150 *mL*) *on dissolved aluminum compounds during the infusion of two commercial types of dry tea leaves* (*black, green*) *with boiling water* (5, 15 *min infusion time*) *are presented. Factors influencing the presence of dissolved aluminum in the infusions of both tea leaves were infusion time and sugar contents, as well as the interaction between ascorbic acid and sucrose* ($p < 0.05$). *Aluminum contents found after* 15 *min of infusion were* 0.7 $mg{\cdot}L^{-1}$ *for black tea infusions added with sugar, and* 0.69 $mg{\cdot}L^{-1}$ *for green tea added with both sugar and ascorbic acid. Both concentrations are higher than the level accepted in Mexico for drinking water (there is no act concerning tea infusions), that is* 0.2 $mg{\cdot}L^{-1}$.

***Keywords*:** *Aluminum Contents*, *Commercial Black and Green Tea Dry Leaves*, *Infusions*, *Sucrose*, *Ascorbic Acid*

1. Introduction

Tea is one of the most popular non alcoholic drinks in the world, particularly in Asia. In the last years tea consumption, and particularly green tea, has increased, due to the general belief that it has beneficial effects to human health such as anti-mutagenic, anti-cancer, and antioxidant properties [1]. Mexico, as other countries, has increased its consumption at an annual rate of 20% [2,3].

Tea leaves (*Camellia sinensis*) are among the most conspicuous vegetal species recognized as aluminum accumulators, reaching contents up to 10,000 $mg{\cdot}kg^{-1}$ [4]. Commercial teas, in spite of the fact of being produced from young leaves shoots, contain relatively high concentrations of aluminum, becoming a potential source of bioavailable aluminum in the diet [5-9]. Matsumoto *et al.* [4] have reported concentrations around 30,000 $mg{\cdot}kg^{-1}$ of aluminum in old tea dry leaves. Ruan and Wong [3] mentioned concentrations of aluminum in some tea varieties from 468 to 930 $mg{\cdot}kg^{-1}$. For many years aluminum has been considered innocuous for human beings [10], since most chemical forms are not damaging for living organisms. However, if pH soil values are low, aluminum tends to form chemical species that are potentially absorbed by plants, especially tea [11,12], and become toxic for living organisms [13]. In this sense, there has been controversy on the impact of this metal on biological systems particularly in the last years [14]. Concerning human health recent studies have demonstrated that bioavailable aluminum is related to some diseases such as Alzheimer, Parkinson, and dialysis encephalopathy [15].

Aluminum concentrations in tea products and its dissolution during the preparation of infusions has been investigated by Flaten [16], Fung *et al.* [12], Moghaddam *et al.* [17], and Wong *et al.* [8,18]. So far, the effects of sucrose and/or lemon juice, as ascorbic acid, on the leaching out of aluminum from the dry tea leaves to water during infusion have not been assessed.

The objective of this research was to quantify the content of dissolved aluminum in commercial green and black dry leaves tea infusions adding or not sucrose and/or ascorbic acid at two infusion times.

2. Materials and Methods

A previous market study was carried out in several Mexico City supermarkets to determine which were the most popular brands of commercial green and black tea among the consumers [19]. As a result two brands, "A" for green tea, and "B" for black tea, were chosen. Two randomly chosen packages of each brand were taken and brought to the laboratories. The contents of several pouches were mixed to have a homogeneous lot for each type of tea that would be subjected to a microwave digestion. A single pouch contents of black and green tea was also taken to corroborate if statistically significant differences were found with the homogenized lot. The covering material of one of the pouches that could be leached out to the infusions (gauzy material) was analyzed to assess if aluminum was detected. From both homogeneous lots 8 samples (4 for each type of tea) were digested in a Berghof-MWS-1 microwave oven (Germany), according to Bárcena-Padilla [19] pre-established conditions. To determine the contents of aluminum of the samples, atomic absorption spectroscopy (AAS) was the technique used. Analyses were carried out in the Laboratory for Atomic Absorption of the UNAM Faculty of Chemistry (Laboratorio de Absorción Atómica de la USAI, Unidad de Servicios de Apoyo a la Investigación, Facultad de Química, UNAM). The same technique was used for the infusions.

2.1. Characterization of the Infusions

A four-factor experimental design with two levels per factor was performed, considering duplicates for all samples. **Figure 1** shows the experimental design.

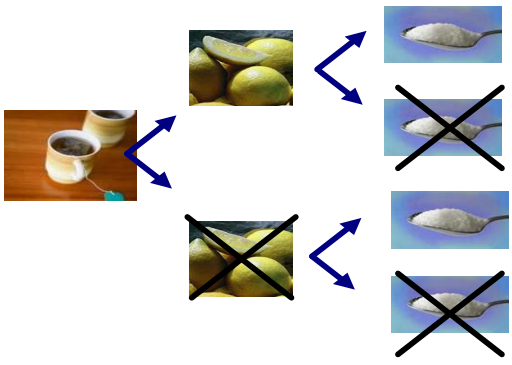

Figure 1. Experimental design for the preparation of green and black tea infusions (5, 15 min) with and without sucrose and ascorbic acid simulating lemon juice.

Factor 1: Tea type (Green and black tea leaves).

Factor 2: Ascorbic acid addition to simulate lemon juice (With and without addition, 2 mL).

Factor 3: Sucrose contents (With and without addition, 2 teaspoons = 5 g).

Factor 4: Infusion time (5, 15 minutes).

Commercial bottle drinking water was brough to boiling temperature and 150 mL were poured on each of the beakers that contained the tea leaves pouches. Sucrose (ca. 5 g), and/or ascorbic acid (ca. 2 mL), were also added. Infusion times considered were 5 and 15 minutes. After the infusion time was over, liquid was drained. There were 32 samples to be digested and sent to AAS analysis. Water was also analyzed to determine its aluminum contents, since in Mexico many potabilization plants use aluminum compounds within the process [20]. Aluminum contents found in water were deducted from the one determined in the infusions.

Statistical analyses of all experimental data were carried out using *Statgraphics Plus* 5.

3. Results and Discussion

Table 1 presents the concentrations of aluminum found in the dry leaves of both commercial teas considered. As mentioned before, black and green tea commercial brands selected were those with the highest demand in several supermarkets, in Mexico City, according to a preference study previously performed [19].

These contents agree with literature data reported by other researchers [3,4,17].

Sucrose and drinking water were analyzed to corroborate its aluminum contents. Also, the material of one pouch was analyzed for aluminum contents.

Table 2 shows the results found. These results indicate that sugar and the pouch material were not a factor to be considered. However, drinking water had very high aluminum contents, probably due to the potabilization methods commonly used in Mexico (that include the addition of alum to flocculate and precipitate water impurities). This amount was deducted from the infusions data obtained from the atomic absorption analyses.

Table 3 shows the data obtained from the infusions obtained for both types of tea. All of them exceed the maximum allowed contents for drinking water of the Mexican Standards, 0.2 $mg \cdot L^{-1}$ or 0.2 $mg \cdot kg^{-1}$ [21].

According to the variance analysis, no significant differences among the two commercial tea dry leaves types, black and gree, were found ($p < 0.05$).

Concerning the infusions, the amount of aluminum transferred to the liquid phase was statistically different depending upon tea type, infusion time, and sucrose presence (**Table 4**).

Table 1. Concentrations of aluminum in commercial black and green dry tea leaves.

	Aluminum contents in dry leaves (ppm or $mg \cdot kg^{-1}$)		Aluminum percentage (% d.m.)		Aluminum contents per pouch of tea (mg)	
	Green tea	*Black tea*	*Green tea*	*Black tea*	*Green tea*	*Black tea*
Media	1322.56	1114.20	0.13	0.11	1.28	1.08
S. D.	256.91	58.61	0.03	0.01	0.26	0.05
V. C.	19.42	5.26	23.07	9.09	20.31	4.62

S. D.: standard deviation, V. C.: variation coefficient, d. m.: dry matter.

Table 2. Concentrations of aluminum found in sucrose, water, and pouches material.

Sample	Aluminum contents (ppm or $mg \cdot kg^{-1}$)
Sucrose	< D. L.
Pouch material	< D. L.
Dinking water (commercial carafe)	1.55

D. L.: Detection limit.

Table 3. Aluminum concentrations in black and green tea infusions.

Treatments	Aluminum in black tea infusions (ppm or $mg \cdot kg^{-1}$) Media	Aluminum in green tea infusions (ppm or $mg \cdot kg^{-1}$) Media
T-5 (5 min infusion)	0.46 ± 0.00	0.61 ± 0.00
T-15 (15 min infusion)	0.65 ± 0.05	0.65 ± 0.05
T-A-5 (5 min, ascorbic acid added)	0.34 ± 0.05	0.57 ± 0.16
T-A-15 (15 min, ascorbic acid added)	0.57 ± 0.05	0.46 ± 0.00
T-S-5 (5 min, sucrose added)	0.53 ± 0.00	0.53 ± 0.00
T-S-15 (15 min, sucrose added)	0.70 ± 0.00	0.61 ± 0.00
T-A-S-5 (5 min, ascorbic acid + sucrose added)	0.65 ± 0.05	0.57 ± 0.05
T-A-S-15 (15 min, ascorbic acid + sucrose added)	0.61 ± 0.00	0.69 ± 0.00

A: ascorbic acid added, S: sucrose added, T: tea leaves.

Table 4. Variability analysis for aluminum dissolved in black and green tea infusions.

Factors	Square values sum	d.f.	Medium Square	Coefficients F	P Value
A) Tea type (green/Black)	0.0047531	1	0.0047531	0.89	0.3570
B) Ascorbic acid	0.0087781	1	0.0087781	1.64	0.2145
C) Sucrose	0.0399031	1	0.0399031	7.45	0.0126
D) Infusion time	0.0552781	1	0.0552781	10.32	0.0042
			Interactions		
A-B	0.0003781	1	0.0003781	0.07	0.7931
A-C	0.0157531	1	0.0157531	2.94	0.1011
A-D	0.0215281	1	0.0215281	4.02	0.0581
B-C	0.0427781	1	0.0427781	7.98	0.0101
B-D	0.0094531	1	0.0094531	1.76	0.1983
C-D	0.0000781	1	0.0000781	0.01	0.9050
Residues	0.112516	21	0.0053578		
Total (Corr.)	0.311197	31			

Quotients F are based on the quadratic mean residual error (d.f. degrees of freedom). P value is the probability of obtaining a *test statistic* (which is a function of the sample; it is considered as a numerical summary of a set of data that reduces the data to one or a small number of values that can be used to perform a hypothesis test) at least as extreme as the one that was actually observed, assuming that the null hypothesis is true (general or default position, such as that there is no relationship between two measured phenomena, or that a potential treatment has no effect).

Irrespective of the type of tea, infusion time is an important factor concerning the amount of dissolved aluminum. In the case of sucrose, it seems this factor is relevant, since its chemical structure may be inducing the release of aluminum from the polyphenol complex structures in tea. This might be an important line of research to be followed in the future, especially in those countries where sugar is added at the time of leaves infusion.

Also, aluminum speciation should be carried out, since some chemical species are more prone to be biologically active [9,22-26].

4. Conclusions and Recommendations

Contents of aluminum in the most widely consumed commercial dry leaves of green and black tea found in Mexico City's supermarkets and its infusions were assessed. Average concentrations are higher in green tea with respect to black tea but the differences were not statistically significant ($p < 0.05$).

Statistically ($p < 0.05$), the most influencing factors in the infusions of both types of tea were the infusion time and the sugar contents (sucrose). Also, the interaction of ascorbic acid and sucrose seemed to play a role, particularly with black tea.

According to the Mexican Standards for drinking water [21], the maximum concentration of aluminum is 0.2 ppm. For the infusions, the drinking water contents were deducted from the total values obtained for all infusions, and even though all of them exceeded this norm.

Commercially sold drinking water in Mexican supermarkets, and used in these experiments, contained 1.55 ppm aluminum, a value far exceeding this limit, a fact that should be assessed by the sanitary authorities in Mexico. Finally, it is recommended to assess the aluminum species found in the dry tea leaves and in the infusions to evaluate its bioavailability for potential consumers [7,9,23,25,27].

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