# The Determination of the Boron Amounts of Teas That Are Sold In Turkey by Using the ICP-OES Technique

E. Moroydor Derun, A. S. Kipcak, O. Dere Ozdemir

***Abstract*—Tea refers to the agricultural products of the leaves, leaf buds, and internodes of Camellia sinensis, prepared and cured by various methods. "Tea" also refers to the aromatic beverage prepared from such cured leaves by combination with hot or boiling water and is the colloquial name for the Camellia sinensis plant itself. Tea is the most widely-consumed beverage after water. It has a cooling, slightly bitter, astringent flavor. The four types of tea most commonly found on the market (in descending order of oxidation) are black tea, oolong tea, green tea and white tea, all of which can be made from the same bushes, processed differently, and in the case of fine white tea, grown differently.**

**In Turkey, mostly tea is produced in the region of Eastern Black Sea. The important tea producers in the world are: India, Sri Lanca, China, Turkey, Kenya, Indonesia, Malawi and Vietnam.**

**In this study the teas selected are: black tea, camomile tea, apple tea, rosehip tea, sage tea, linden tea and green tea, which are produced by Lipton. Optical emission spectroscopy (ICP-OES) was used to determine the boron amount that is introduced to the human body while drinking, by the method of brewing the teas. These teas were brewed with 90-100°C hot water for 5 minutes and the obtained filtrates' boron concentrations were determined by Inductively Coupled Plasma-Optical Emission Spectroscopy technique.**

**The boron content in the tea results of the experiments vary between the values of 0.084 and 2.023 ppm.**

***Index Terms*—Boron, tea, ICP-OES, hot water brewing**

## I. Introduction

Boron is the chemical element with atomic number 5 and the chemical symbol B. Several allotropes of boron exist: amorphous boron is a brown powder; whereas crystalline boron is black, extremely hard (about 9.5 on Mohs' scale), and a poor conductor at room temperature. Elemental boron is used as a dopant in the semiconductor industry, while boron compounds play important roles as light structural materials, insecticides and preservatives, and reagents for chemical synthesis. Boron is a relatively rare element in the Earth's crust, representing only 0.001%. The worldwide commercial borate deposits are estimated as 10 million tons. Turkey and the United States are the world's largest producers of boron. Turkey has almost 72% of the world's boron reserves. Boron does not appear on Earth in elemental form but is found combined in borax, boric acid, colemanite, kernite, ulexite and borates [1-7].

Boron is an essential plant nutrient. The lack of it results in boron deficiency disorder, high soil concentrations of boron may also be toxic to plants. As an ultratrace element, boron is necessary for the optimal health of rats and presumably other mammals, though its physiological role in animals is not yet fully understood. Total daily boron intake in normal human diets ranges from 2.1–4.3 mg boron/day [8-10].

According to Dart (2004), boron toxic effects in humans have been previously well described and were observed especially in subjects with gastrointestinal symptoms that persistent nausea, vomiting, diarrhea, epigastric pain, hematemesis and blue-green discoloration of feces; central nervous symptoms, hyperexcitability, opisthotonus, tremors, irritability, depression convulsions, excitement, restlessness, weakness, lethargy, headaches, delirium and coma due to acute over dosage. Renal effects are renal tubular damage, oliguria and elevated serum creatinine. The most known B cardiovascular effects with acute over dosage are: tachycardia and hypotension.

Tea is a traditional beverage made from steeping the processed leaves, buds, or twigs of the tea bush (Camellia sinensis) in water. The Camellia sinensis is an evergreen native of China. It takes a variety of forms, growing 15 to 20 meters tall, with leaves ranging from smooth and shiny to fuzzy and white-haired. The plant gives rise to more than 3000 varieties of tea worldwide, which can be roughly classified into six basic categories: white, green, oolong, black (the Chinese call these red teas), pu-erh, and flavored. Some specialists would add another category, blends. And then there are countless herbal infusions, informally referred to as "tea" but entirely unrelated to "real" tea made from Camellia sinensis leaves [12].

Many researches in this area including tea and boron are done analytically using ICP-OES or AAS. Gallaher et al. (2004) studied many herbal infusions (teas) for their impact on health. The purpose of this study was to determine the mineral content of 10 commercially available dry teas and the infusions produced from them. Herbal infusions studied included commercial blends of peppermint, Echinacea, red clover, Siberian ginseng, dandelion, red raspberry leaf, blueberry leaf and green tea. None of the infusions was a

Manuscript received April 12, 2010. The Determination of the Boron Amounts of Teas That Are Sold in Turkey by Using the ICP-OES Technique.
Emek Moroydor Derun is with the Yildiz Technical University, Chemical Engineering Department, Istanbul, Turkey (phone: +90 212 383 4655; fax: +90 212 383 4725; e-mail: moroydor@yildiz.edu.tr).
Azmi Seyhun Kıpçak is with the Yildiz Technical University, Chemical Engineering Department, Istanbul, Turkey (e-mail: skipcak@yildiz.edu.tr).
Ozgul Dere Ozdemir is with the Yildiz Technical University, Chemical Engineering Department, Istanbul, Turkey (e-mail: odere@yildiz.edu.tr).

good source of Ca, Mg, P, K, Na, Cu, Fe, Mn, or Zn in a single serving. K levels were high enough that 3.5 cups of dandelion infusion and 4.5 cups of Echinacea infusion provided a good source (10% Daily Value).

Lopez-Garcia et al. (2008), studied alternative procedures for the electrothermal atomic absorption spectrometric determination of boron in milk, infant formulas and honey samples. For both infant formulas and milk samples, due to their very low boron content, they used a procedure based on preconcentration by solid phase extraction (Amberlite IRA 743), followed by elution with 2 mol $L^{-1}$ hydrochloric acid. Detection limits were 0.03 µg $g^{-1}$ for 4% m/v honey, 0.04 µg $g^{-1}$ for 5% m/v infant formula and 0.08 µg $mL^{-1}$ for 15% v/v cow milk.

Yazbeck et al. (2005), studied to evaluate health impact of boron in drinking water. A regional scale geographical study in Northern France was conducted. The results showed that after necessary adjustments, men living in municipalities with more than 0.30 mg $L^{-1}$ of boron in drinking water had elevated but not significant boron blood levels compared with those living in municipalities with boron water levels of less than 0.30 mg L-1. The results of this study do not support the idea of a deleterious effect of boron on human health, at the boron water level contents found in this specific region. In fact, there is a tendency toward a beneficial effect with low-dose environmental exposure in drinking water.

Krejcova and Cernohorsky (2002) investigated the determination of boron by the method of optical emission spectrometry with inductively coupled plasma. The efficiency of microwave digestion technique and hot water extraction was studied. The method was applied to the analyses of hot water extracts of tea and coffee samples. The mean extracted amount of boron ranged from 3.21 ± 0.17 to 9.25 ± 0.421 mg $kg^{-1}$ in black teas; 3.5 ± 0.12 to 5.52 ± 0.15 mg $kg^{-1}$ in green teas; 2.71 ± 0.13 to 27.7 ± 0.9 mg $kg^{-1}$ in fruit teas; 13.3 ± 0.4 to 21.3 ± 0.7 mg $kg^{-1}$ in instant coffees and from 7.57 ± 0.26 to 17.5 ± 0.5 mg $kg^{-1}$ in ground roasted coffee beans.

The aim of this study was to determine the boron concentrations in defined teas that are prepared by the preparing method, called infusion. Traditional drinking behaviors affect the human health. Since the boron concentrations were very important, this study has significant importance for the society.

## II. Metodology

The analyzed tea samples obtained from the local market in Istanbul, Turkey. Seven types of teas, black tea, camomile tea, apple tea, rosehip tea, sage tea, linden tea and green tea were prepared by the brewing method of infusion.

### A. The Brewing Method

In the case of tea infusion, 50 mL of hot water (90-100°C) was poured to 1 gram of tea in the beaker and stirred. After 5 minutes, the extract was filtered into a 100 mL volumetric flask, 1 mL concentrated nitric acid was added, filled up with ultra pure water [16-17].

### B. Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES)

In ICP-OES technique, the sample is subjected to high temperatures that cause excitation and/or ionization of the sample of atoms. This excited and ionized atoms are then decayed to a lower energy state through the emission. The intensity of the light emitted at a specific wavelength to the element of interest is measured [18].

The Spectrometer used in the experiments and samples are given in Fig. 1. Perkin-Elmer Optima 2100 DV model Inductively Coupled Plasma Optical Emission Spectrometer equipped with an AS-93 autosampler was used. Measurement conditions were adjusted to a power of 1.45 kW, plasma flow of 15.0 L $min^{-1}$, auxiliary flow of 0.8 L $min^{-1}$ and nebulizer flow of 1 L $min^{-1}$. The calibration was fit into a linear range and represented in Figure 2. Used standards were prepared in the range from 0.05 to 10 mg $L^{-1}$. The water used for tea brewing was analyzed for boron contents.

Fig. 1. Tea samples and Perkin Elmer Optima 2100 ICP-OES Spectrometer

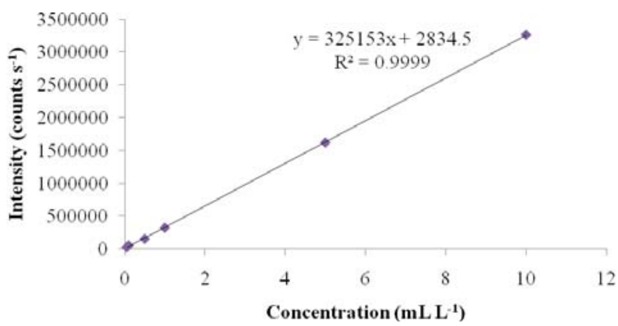


Fig. 2. The calibration set of Boron

## III. Results and Discussion

The boron concentrations in the samples are measured by ICP-OES. The results obtained are presented in Fig. 3.

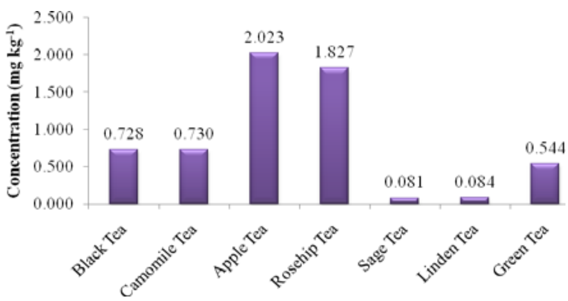


Fig. 3. Results of ICP-OES analyses of the selected teas

According to the results the boron contents sage and linden teas are nearly the same and yielded the lowest values. These values are followed by green tea, with a content of 0.544 mg $kg^{-1}$. Black and chamomile teas had similar values and higher boron contents than that of the green tea. Rosehip tea had a boron content of 1.827 mg $kg^{-1}$ and takes the second place, then the highest content was found in the apple tea with a value of 2.023 mg $kg^{-1}$.

## IV. Conclusion

The research and the quantitative estimate of boron element is of particular interest to assure its nutritional integrity and so the human health. The results indicate that B content varies between 0.0081 – 2.023 mg $kg^{-1}$ in the seven types of teas. These analyses are compared with upper limit for boron which is given in the Table 1. The determined boron contents of these teas and the calculated values for a single tea-bag are given in Table 2. From the results, none of the investigated teas create a health risk stand alone even for people who are tea addicts.

Table 1. Upper limits for boron [19]

| Life Stage Group | Age | Upper Limit (mg $day^{-1}$) |
|---|---|---|
| Children | 1-3 | 3 |
| | 4-8 | 6 |
| | 9-13 | 11 |
| Adolescents | 14-18 | 17 |
| | 19-70 | 20 |
| | >70 | 20 |
| Pregnancy | ≤18 | 17 |
| | 19-50 | 20 |
| Lactation | ≤18 | 17 |
| | 19-50 | 20 |

Table 2. Experimental values of tea boron contents

| Tea Type | Boron Content (mg $kg^{-1}$) | Boron Content for a Single Tea-bag (~2g) |
|---|---|---|
| Black Tea | 0.728 ± 0.055 | $1.456 \times 10^{-03} \pm 0.110 \times 10^{-03}$ |
| Camomile Tea | 0.730 ± 0.048 | $1.460 \times 10^{-03} \pm 0.096 \times 10^{-03}$ |
| Apple Tea | 2.023 ± 0.782 | $4.045 \times 10^{-03} \pm 1.560 \times 10^{-03}$ |
| Rosehip Tea | 1.827 ± 0.083 | $3.654 \times 10^{-03} \pm 0.166 \times 10^{-03}$ |
| Sage Tea | 0.081 ± 0.028 | $0.162 \times 10^{-03} \pm 0.055 \times 10^{-03}$ |
| Linden Tea | 0.084 ± 0.023 | $0.168 \times 10^{-03} \pm 0.045 \times 10^{-03}$ |
| Green Tea | 0.544 ± 0.028 | $1.087 \times 10^{-03} \pm 0.055 \times 10^{-03}$ |

## Acknowledgment

We would like to thank Prof.Dr. Sabriye Piskin for her great contribution to our study.

## References

[1] P. Argust, “Distribution of boron in the environment”, Biological Trace Element Research 66 (1–3): 131–143, 1998.

[2] W. G. Woods, “An Introduction to Boron: History, Sources, Uses, and Chemistry”, Environmental Health Perspectives 102, Supplement 7, Retrieved 2008-09-20, 1994.

[3] D. S. Kostick, “Mineral Yearbook: Boron” (PDF), United States Geological Survey, 2006, Retrieved 2008-09-20,

[4] “Mineral Commodity Summaries: Boron” (PDF), United States Geological Survey, 2008, Retrieved 2008-09-20.

[5] “Developments in the Economic Sector (of Turkey)”, Turkish government. Retrieved 2007-12-21.

[6] R. Simmons, N. Ahsian, H. Raven, *The Book of Stones: Who They Are and What They Teach*, North Atlantic Books, 2007. pp. 421–422. ISBN 1556436688.

[7] T.R. Prime Ministry State Planning Organization, 2006. Ninth development plan (2007–2013). Chemical Industry Private Expertise Commission, Boron Operations Group Report (e.g., pp.8-61).

[8] F. H. Nielsen, “Ultratrace elements in nutrition: Current knowledge and speculation”. The Journal of Trace Elements in Experimental Medicine 11 (2–3): 251–274, 1998.

[9] United States, Environmental Protection Agency, Office of Water, U. S. Environmental Protection Agency Staff Health advisories for drinking water contaminants: United States Environmental Protection Agency Office of Water health advisories, CRC Press, p.84, ISBN 087371931X, 1993.

[10] L. Silverman, K. Trego, “Corrections-Colorimetric Microdetermination of Boron By The Curcumin-Acetone Solution Method”, Anal. Chem. 25: 1639, 1953.

[11] R.C. Dart, Medical Toxicology, Lippincott Williams & Wilkins, 2004, pp. 1322.

[12] http://www.starchefs.com/features/tea/html/types.shtml (retrieved 12.01.2010).

[13] R.N. Gallaher, K. Gallaher, A.J. Marshall, A.C. Marshall, “Mineral analysis of ten types of commercially available tea”, Journal of Food Composition and Analysis 19: S53-57, 2006.

[14] I. Lopez-Garcia, P. Vinas, R. Romero-Romero, M. Hernandez-Cordoba, “Preconcentration and determination of boron in milk, infant formula, and honeysamples by solid phase extraction-electrothermal atomic absorption spectrometry”, Spectrochimica Acta Part B 64: 179-183,2009.

[15] C. Yazbeck, W. Kloppmann, R. Cottier, J. Sahuquillo, G. Debotte, G. Huel, “Health impact evaluation of boron in drinking water: a geographical risk assessment in Northern France”, Environmental Geochemistry and Health 27: 419-427, 2005.

[16] A. Krejcova, T. Cernohorsky, “The determination of boron in tea and coffee by ICP–AES method”, Food Chemistry 82: 303–308, 2003.

[17] O.D. Ozdemir, A.S. Kıpcak, E.M. Derun, N. Tugrul, M.B. Piskin, “The Analysis of the Boron Amounts in Coffees by The Method of ICP-OES”, 1st Conference on Chemical Engineering and Advanced Materials (CEAM) VIRTUAL FORUM, Naples 2009.

[18] C. Zhang, *Fundamentals of Environmental Sampling and Analysis*, Wiley-Interscience, 2007.

[19] P. M., Coates, *Encyclopedia of dietary supplements*, CRC Press, 2005.