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Original Research Article

Levels of essential and non-essential elements in black teas commercialized in Poland and their transfer to tea infusion

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ABSTRACT

Twelve bagged black tea samples available in Poland were analyzed for P, K, Ca, Mg, Na, Fe, Mn, Zn, and Al concentrations both in leaves and their infusion. In dry tea the most abundant element among the macroelements was K followed by P, Mg and Ca, whereas the Al content was prominent among the trace metals tested, followed by Mn, Fe and Zn. Both macroelements and trace metals were extracted from the black tea leaves to tea infusion. The results showed that the percentage transfer differed significantly among all elements. The solubility of Ca and K was the highest among the elements studied and averaged 63.8% and 60.7%, respectively. The percentage transport of trace elements was also relatively high except for Fe, which was insoluble, and its content remained higher in the solid particles during beverage preparation.

1. Introduction

Tea is one of the most popular beverages all over the world. It is prepared from the leaves of a shrub *Camellia sinensis* (Salahinejad and Aflaki, 2010). Some 75% of the estimated 2.5 million tons of dried tea harvested annually in the world is manufactured as black tea (AL-Oud, 2003). In Poland, tea comprises over 40% of the beverages consumed in winter, and almost 25% in summer. One kilogram of tea is consumed per person per year on average. An average consumer drinks 2–3 cups of tea every day (Wojciechowska-Mazurek et al., 2010).

Various studies have proved that tea consumption has both positive and negative effects on human health (AL-Oud, 2003; Salahinejad and Aflaki, 2010). Tea infusion may be an important source of essential major dietary inorganic elements such as calcium, magnesium, potassium, fluoride. Tea leaves are also a source of mineral elements such as zinc, manganese, iron, copper, magnesium, titanium, aluminum, strontium, bromine, sodium, potassium, phosphorous, iodine and fluorine (Mossion et al., 2008; Seenivasan et al., 2008). Previous research showed that *C. sinensis* (tea tree) is an aluminum-accumulating plant (Mossion et al., 2008). It also tolerates and accumulates elevated quantities of F and Pb (Szymczycha-Madeja et al., 2012).

During tea infusion, both essential mineral elements and toxic metals are extracted into the beverage (Szymczycha-Madeja et al., 2012), and trace metals consumed in tea cause harmful effects on the human body. The main sources of trace metals in plants are their growth media, nutrients, soil and agrochemical inputs, including pesticides and fertilizers (Seenivasan et al., 2008). Previous research showed that the high concentration of trace metals in tea products is connected with planting tea shrubs in highly acidic soils where trace metals are more bioavailable (Karak and Bhagat, 2010). Metallic constituents and macroelements in tea leaves differ according to the type of tea, determined by the technology of tea processing and growth media (i.e. soils and their characteristics, the geological structure) (AL-Oud, 2003; Szymczycha-Madeja et al., 2012). Therefore, manufacturing processes and the role of cultivation may affect element contents.

In the present study it has been hypothesized that *C. sinensis* leaves contain high amounts of both macroelements and trace metals, but not all of them are leached from tea to the infusion. To verify this hypothesis, concentrations of certain macroelements: phosphorus, potassium, calcium and sodium (P, K, Ca, Na), and trace metals: zinc, manganese, iron and aluminum (Zn, Mn, Fe, Al) in dry black tea samples and in tea infusions were determined and compared. The objective of the study was to evaluate the

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Table 1
Description of 12 brands of commercially purchased teas.

Tea sample	Name	Origin	Producer/importer	Tea weight per bag [g]	Steeping time[a] [min]
1	Grande express tea	Argentina and Vietnam	Kaufland	1.5	3–5
2	Herbapol	South India (Nilgiri)	Herbapol-Lublin S.A.	2.0	3–5
3	Tetley intensive	Central India (The Valley of Brahmaputra River)	Tata Tetley Limited	2.0	3
4	Dilmah	Ceylon (Sri Lanka)	Gourmet Foods	2.0	5
5	Ahmad tea, English tea no. 1	Ceylon (Sri Lanka)	Ahmad tea LTD	2.0	3–5
6	Yunnan	China	ROGER Sp. z o.o.	1.7	3–5
7	Yunnan	China	Oskar International Trading Sp. z o.o.	2	5
8	Madras	India, Indoniesia	ROGER Sp. z o.o	1.7	3–5
9	Loyd tea	Kenya, Malawi	MOKATE S.A.	2.0	4–5
10	Lipton yellow label tea	Indefinite origins	Unilever Polska S.A.	2.0	3
11	Minutka	Indefinite origins	MOKATE S.A.	1.4	5
12	Saga, express tea	Indefinite origins	Unilevert Polska S.A.	1.4	1–2

[a] According to the instructions given by tradesmen.

percentage transfer of the elements tested to the brew and determine concentrations of macroelements and trace metals commonly available in black tea brands available in Poland.

2. Materials and methods

Twelve commercial bagged black teas were purchased at the local stores in Wrocław, Poland in September 2011 (Table 1). Each box, which contained 20–100 infusion teabags, each with 1.4–2 g of broken leaves, was sealed to keep out moisture.

2.1. Mineral analysis of dry tea material

Prior to analysis, the contents of 5 infusion bags randomly selected from each box of tea were mixed, dried at 50 °C to constant weight and ground into fine powder in a laboratory mill IKA Labortechnik M20 (IKA®-WERKE GMBH & Co., KG Staufen, Germany). For the determination of total element concentrations in tea leaves, homogenized material (1 g) was subsequently digested in an open system with concentrated nitric acid (65%, ultra pure, 5 mL) and hydrogen peroxide (30%, ultra pure, 1 mL), during which the temperature was raised to 95 °C until the evolution of nitrous oxide gas stopped and the digest became clear. After cooling to room temperature the digests were diluted to 100 cm^3 with deionized water in volumetric flasks and then filtered. Ca, K and Na were analyzed using a JENWAY Ltd. PFP7 flame photometer (Bibby Scientific Limited, Group HQ, Stone, Staffordshire, UK) and P by FIA compact from MLE GmbH (Dresden, Germany). Mg, Al, Fe, Mn and Zn concentrations were determined using FAAS with an AVANTA PM Atomic Absorption Spectrophotometer from GBC Scientific Equipment Ptv. Ltd. (Dandenong, Victoria, Australia).

2.2. Mineral analysis of infusion liquid

Prior to analysis, the contents of 5 infusion bags randomly selected from each box of tea were mixed, dried at 50 °C to constant weight and ground into fine powder in an IKA Labortechnik M20 laboratory mill. Tea infusions were prepared by boiling 80 cm^3 of deionized water and pouring the boiling water over 2.0 g of broken tea leaves into a standardized Erlenmeyer flask. The tea infusion was stirred with a glass rod to ensure proper wetting, covered and steeped for exactly 5 min, which is the tea industry's recommended brew time; the solubility of elements is highest in the first 5 min of infusing (Szymczycha-Madeja et al., 2012). Subsequently, the steeped infusion was filtered through filter paper into a volumetric flask and diluted with deionized water to 100 cm^3 (Salahinejad and Aflaki, 2010; Mehra and Baker, 2007). P, Ca, Mg, Na, Al, Fe, Mn and Zn concentrations were determined using the methods described above. Iron concentration in some of the tea infusion samples was found to be below the detection limit of 0.005 mg/kg.

2.3. Quality control

All laboratory glassware used in analyses was acid cleaned. Deionized water was used throughout the experiment to prepare all the solutions. All chemicals and reagents employed were of analytical grade purchased from Chempur® (Piekary Śląskie, Poland). The precision of the measurements was determined by comparing the results of trace metal concentrations in the solutions made from three separate weighted portions of each sample, analyzed using identical methods. The results were calculated on a dry weight basis.

Blank samples were prepared by following the procedure for dry tea material and tea infusion using samples of deionized water without tea. The reproducibility of the methods used was compared to the results of an inter-laboratory study through digesting, and also by analysing reference material Bush Branches and Leaves, NCS DC73348 LGC standards (China National Analysis Center for Iron & Steel, Beijing, China). The recovery rates, relative to the results of reference material, are given in Table 2. All elements were determined against standards containing the same matrix as the samples and subjected to the same procedure. Atomic absorption standard solutions of Al, Mg, Mn, Zn, and Fe at a concentration of 1.000 mg/L and atomic spectroscopy standard concentrations of Ca, Na, K (1.00 g) were obtained from Sigma–Aldrich Ltd. (Poznań, Poland).

2.4. Data analysis

Statistical differences between particular tea brands with respect to mean concentrations of elements were evaluated by ANOVA on log-transformed data to obtain normal distribution of features (Zar, 1999). The normality of the analyzed features was checked by Shapiro–Wilk's test and the homogeneity of variances by Bartlett's test (Sokal and Rohlf, 1995). Pearson regressions and correlation coefficients ($n = 36$) were calculated to examine relationships between the concentrations of the elements in tea leaves (Parker, 1983). Statistical confidence was set at $\alpha = 0.05$. The percentage extraction of each mineral was determined for the dry tea and the hot water extract analysis by the following ratios: element concentration in tea infusion/element concentration in blended tea leaves ($\times$100%). All statistical calculations were carried