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ORIGINAL PAPER

Lithium content in the tea and herbal infusions

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Abstract Tea infusions provide many valuable nutrients, including elements. Lithium (Li) is an element which appears rather in small amounts both in environment and in the human tissues or body fluids. Now it is known that it plays a part in many important vital functions. Content of Li in food products is generally small, which is associated with its low consumption. The aim of the study was to examine the concentration of Li in the infusions prepared from different sort of teas available in the market. The content of Li was examined in 55 infusions of black, green, red, fruit and herbal teas. Quantitative studies were performed using atomic absorption spectrometry with atomization in graphite furnace. The largest amount of Li was extracted from the leaves of red tea and rooibos as well as some herbal teas. The determined content of Li in tea infusions was in the range 0.02–1.36 µg/g of tea, and 1 cup (250 mL) of analysed infusions (together with a tap water) provides 2.2–3.0 µg of Li.

Keywords Lithium · Teas · Herbs · Infusions · GFAAS

Introduction

So far, little is known about the content of Li in living organisms and its role in life processes. In human body is about 7 mg of Li. Concentration of this element in human physiological fluids and tissues is rather low: plasma 1.8–18.8 µg/L, blood 0.4–1.0 µg/L (in patients undergoing therapy with Li up to 1000 times more), urine 12 µg/L (4,6–219 µg/L) and 9.6 µg/L (median value), breast milk <1 µg/L and hair 0.003–0.042 µg/g. Most Li was found in the brain, kidney, liver and erythrocytes. Larger amounts of Li were determined in body fluids and tissues of women than men. Nearly 100 % of Li is absorbed from the gastrointestinal tract (small intestine) and is excreted mainly (over 90 %) by the kidneys. Amount of Li excreted in the urine per day is one of the indicators of daily dietary intake of this element and ranges from 25 to 100 µg/day [1–7]. According to our research (unpublished data), the amount of Li in 24-h urine samples was measured at the level of 12.9 µg/L (median 8.1 µg/L, range 3.6–130.9 µg/day, $n = 8$), which may define a daily supply of this element with food.

Li transport into the cell occurs via passive diffusion and active transport by using Na^+/K^+ pump (ATPase). In biochemical processes, Li competes with elements such as Na, K, Mg, Ca, Cu, Zn, Rb, Mn and Co. Among others, it reduces amount of intracellular K. Li forms compounds with higher stability than Na and K, but lesser than Ca and Mg. Li affects the activity of several enzymes (e.g. adenylyl cyclase, inositol phosphatase, Na^+/K^+ATPase, tyrosine and tryptophan hydroxylases), reduces activity in the dopaminergic and noradrenergic systems but enhances the other neurotransmitters function as GABA, serotonin and acetylcholine. Li decreases blood glucose levels and thus way may prevent atherosclerosis and heart diseases. Li may play a role in the transport and distribution of folate and vitamin B_{12} as well as in blood clotting. It was observed that Li deficiency in animals can result in growth inhibition and lower birth weight. In humans, the symptoms of deficiency of this element have not been described yet. However, relationships

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were observed between low supply of this element in drinking water and the mood and personality disorders, occurrence of psychosis and depression, increased susceptibility to addiction, increased aggression and sleep disorders. Li is used in psychiatry for over 60 years as a drug in the treatment of manic-depressive states. The amount of Li salt (mainly as Li_2CO_3) administered orally in a daily dose is usually 800–2000 mg. Side effects that may occur after ingestion of excessive amounts of lithium include allergies, polyuria, digestive, neurological, endocrine, cardiovascular and dermatology dysfunctions [6, 8–12].

Little is known about the consumption of Li and its content in food. Studies on this issue are fragmentary and incomplete. As it is known so far, food products provide the following amounts of Li (µg/kg): grain 34.7, vegetables 9.4, fruits 14.0, fish 21.9, meat 9.0, milk 2.2, wine 7.09–8.99 µg/L, salt 0.67–2.34 and mineral waters even to 100 mg/L [1, 13–15]. Natural environment significantly affects the Li content in food. The main sources of Li in diet seem to be cereals, fruits, vegetables, beverages and mineral waters [6, 16–18]. Schrauzer [6] suggested provisional recommended dietary allowance (provisional RDA) of 1 mg Li for a person weighing 70 kg. Daily intake of Li by the authors is in the range <1–3100 µg. The inhabitants of USA, Canada, Japan and Europe, except for Sweden, consume much less Li than the recommended amount, for example (µg/day): Canada 21.6, USA 25–62, Japan 3.3, Belgium 3.8–13.2, Italy 16.2–44.6, Spain 10.9–104.7, Turkey 29.3–50.9, UK 107 and Germany 201–539 [6, 19]. The amount of Li provided in the daily food rations served to the students of the Main School of Fire Service in Poland (without bakery product and beverages and taking into account the content of Li in post-consumer waste) was 10.7 µg [20].

In the light of available knowledge, it should be emphasized that role of Li in life processes is still not fully understood. Authors [6, 8, 12] underlined that Li has a role in the function of bone marrow, prevention of atherosclerosis, heart diseases, diabetes, hypertension, neurodegenerative conditions, alcohol addiction and mental disorders. On the other hand, daily intake of Li in diet is rather insufficient. Therefore, we undertook an attempt to assess the content of Li in teas and herbal infusions as a potential source of this element, particularly because tea is one of the most consumed beverages in the world.

Materials and methods

Materials

The analysed teas and herbal teas (leaves and bags) were purchased in the local markets in Warsaw, Poland. The study included 55 types of teas: 16 black, 9 green, 7 red, 11 fruity and 12 herbal. To create groups of teas, we have taken into account their raw material composition, technological processes carried out and nomenclature used by the manufacturer. Moreover, in the group of fruit teas, we additionally included two teas which the main component were leaves of rooibos. In Tables 1 and 2, trade names of investigated teas were presented.

Infusions preparation

Duplicate infusions were prepared strictly according to the recommendations of producers regarding the amount of tea leaves, temperature and time of tea brewing. Each portion of tea leaves and bags was exactly weighed. Samples of tea leaves (0.9474–3.8425 g) or bags (1.1737–3.5506 g) were placed into 250 mL bakers, and then about 200 mL of hot (80–100 °C) tap water from the municipal water supply network was added. Samples were left under a cover for 2–15 min. In some cases, decoctions of herbs were prepared by heating a sample on a hot plate during the time according to the producer indications. Next, beverages were transferred into a 250-mL volumetric flask and filled up to the mark with the tap water. If there was such a need, infusions were filtered through blue filter papers (Munktell & Filtrak). The pH values were measured in infusions to estimate relationships between its quantity and the amount of Li leached to infusion. This way, 10-mL portions of acidified with 65 % HNO_3 (Cheman Ciech) extracts were prepared to instrumental analysis. To control the content of Li in tap water and the possibility of samples contamination, simultaneously, two blanks with each series of tea infusions were made.

Instrumental analysis

The content of Li in the samples was determined by atomic absorption spectrometry (AAS) using a spectrometer AVANTA Σ (GBC). Quantitative analysis was performed in a graphite furnace (GFAAS) GF3000 with an autosampler PAL3000. Measurements were taken in the pyrolytically coated tubes under an atmosphere of inert gas–argon (Ar) in the following conditions: wavelength 670.8 nm, the temperature of pyrolysis and atomization 800 and 2400 °C and the range of calibration curve 1.0–10.0 ng/mL. Working standards were prepared from stock solution (Merck) at concentration of 1000 mg/L. The volume of sample dispensed into the furnace was 10 µL. As a matrix modifier NH_4NO_3 (Aldrich) in amount of 100 µg was used.

Validation of analytical method

To establish the correctness of the elaborated and applied analytical procedure, an appropriate validation was

Table 1 Li content in infusions of black, green and red teas (μg) per 1 g of tea

Black		Green		Red	
Dilmah—garden fresh unblended	0.39 ± 0.09	Dakir—green and white*	0.18 ± 0.11	Bio-active Pu-Erh with grape-fruit juice	0.77 ± 0.08
Ahmad tea—London english tea	0.27 ± 0.06	Green tea with opuntia	0.17 ± 0.02	Haichao tea blocks Pu-Erh*	0.47 ± 0.01
Irving—traditional earl grey	0.34 ± 0.03	Green tea with lemon	0.26 ± 0.06	Lipton Pu-Erh melon-apple	0.43 ± 0.02
Tetley—earl grey intensive	0.32 ± 0.01	Green tea*	0.02 ± 0.02	Bio-active Pu-Erh with lemon flavour*	0.75 ± 0.06
Dilmah—supreme ceylon single orgin*	0.27 ± 0.12	Dilmah—green tea with jasmine flowers*	0.18 ± 0.08	Vitax inspirations—Pu-Erh and Grejpfrut	1.12 ± 0.16
Dilmah—single estate darjeeling*	0.26 ± 0.02	Oskar green tea bags—Yunnan style	0.11 ± 0.01	Oskar-Yunnan Pu-Erh tea*	0.31 ± 0.05
Assam	0.57 ± 0.09	Sir Edward tea—green tea with seaweeds	0.28 ± 0.04	Sir Roger Pu-Erh*	0.68 ± 0.14
Teekanne—earl grey	0.46 ± 0.11	Shuanglong ting special gun-powder*	0.12 ± 0.05		
Lipton—yellow label	0.38 ± 0.06	Yunnan—de luxe-white tea*	0.37 ± 0.06		
Saga (granulated)*	0.54 ± 0.10				
Saga	0.72 ± 0.01				
Yunnan*	0.69 ± 0.08				
Twinings of London—earl grey	0.36 ± 0.02				
Lipton—yellow label (granu-lated)*	0.24 ± 0.04				
Punjana everyday tea	0.24 ± 0.05				
PG tips the strong one	0.37 ± 0.03				

* leaf tea

Table 2 Li content in infusions of fruity and herbal teas (μg) per 1 g of tea

Fruity		Herbal	
Taste of nature—raspberry tea	0.39 ± 0.10	Mint	0.36 ± 0.15
Melissa with pear	0.18 ± 0.09	Slim-figure	0.16 ± 0.05
Tea garden—cranberry	0.22 ± 0.07	Chamomile	0.42 ± 0.20
Minutka with raspberry, strawberry and pomegranate	0.18 ± 0.06	Herb—epilobium parviflorum*	0.57 ± 0.12
Tea garden—wild rose (fruits)	0.05 ± 0.03	Sage	0.51 ± 0.04
Tea garden—raspberry and wild rose (fruits)	0.10 ± 0.07	St. John's wort	0.11 ± 0.06
Forest fruits tea	0.28 ± 0.08	Melissa with orange	0.14 ± 0.08
Wild rose (flowers)*	0.39 ± 0.07	Herbs monk	0.21 ± 0.00
Hibiscus*	0.40 ± 0.28	White mulberry leaf	0.41 ± 0.12
Lord tea—rooibos sense—orange and cinnamon	0.46 ± 0.08	Jasmine green–Yunnan style*	0.19 ± 0.00
Bio-active—rooibos with honey	0.80 ± 0.10	Nettle leaf*	1.36 ± 0.18
		Horsetail herb*	0.81 ± 0.15

* leaf tea

performed. Validation parameters of procedure used for Li measurement were as follows: recovery 96–100 %, characteristic mass 1.2 pg, precision of method 1.5 % and limit of detection (LOD) 0.4 ng/mL (calculated from: 3.3 × SD/a, where: SD standard deviation for blanks, a the slope of calibration curve). Unfortunately, there are no suitable certified reference materials for Li content in biological media. In the few materials, its quantity is only reported. We determined the content of Li in beef liver (SRM 1577b) in the amount of 181 μg/kg, and this concentration is similar to the value obtained by other authors [17] 0.164 mg/kg (0.144–0.200 mg/kg).

Table 3 Li content in teas infusions (excluding tap water), its mean values per 1 g of tea and their range

Teas	Range (μg)	x ± SD (μg g^{-1})	Range ($μg^{-1}$ g)
Black	0.58–1.35	0.40 ± 0.16	0.21–0.75
Green	0.07–0.53	0.19 ± 0.10	0.02–0.37
Red	0.72–1.70	0.64 ± 0.27	0.30–1.12
Fruity	0.18–1.82	0.32 ± 0.28	0.05–0.80
Herbal	0.24–1.29	0.44 ± 0.36	0.11–1.36

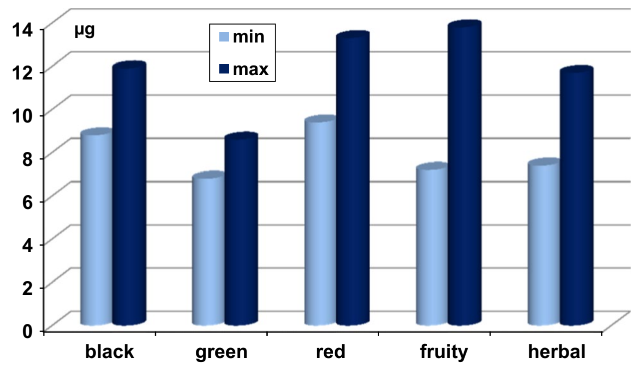

Fig. 1 Minimum and maximum total content of Li in 1 L of teas infusions (including tap water)

Statistical analyses

Statistical analyses were performed using *Statsoft* STATISTICA version 9.1. Results were expressed in the form of arithmetic mean (x) ± SD. Analysis of variance (ANOVA) was used to compare results in groups of teas (Kruskal–Wallis test, $p < 0.05$) and Spearman's test for correlation analysis between variables.

Results and discussion

Tea leaves and herbs contain many valuable nutrients, and compounds that determine the taste infusions and their therapeutic and refreshing properties. Teas are a source of such compounds as polyphenols (including tannic compounds, for example, tannin) carbohydrates, proteins, fats, organic acids, volatile substances (alcohols, esters, cyclic compounds), alkaloids (caffeine, xanthine, theobromine, and theophylline), vitamins, ash, macro- and microelements. In tea leaves, mainly flavonols, catechols, tannins and polyphenols have complexing properties with respect to metals. Herbal infusions contain biologically active compounds, enzymes, vitamins, essential and trace elements [21–23].

The mineral composition of tea leaves depends on the environmental conditions, the species of tea, age of bush and carried out technological processes (e.g. drying, fermentation). In contrast, element content in infusion is determined by such factors as kind and level of organic and inorganic matrix, solubility of complex compounds, the type of water used for preparing a brew, the conditions of extraction (the amount of tea per volume of water, its temperature, an area of extraction, the pH, time of infusion) and contaminations [21–23].

Li content in black, green, red and fruity teas as well as herbal infusions extracted from 1 g of teas is being presented in Tables 1 and 2. Results were reduced by Li content in tap water. Table 3 shows the minimum and maximum quantity of Li extracted from weighted amount of tea leaves or tea bags in 250 mL of water as well the mean Li amount calculated per 1 g of tea in all the groups. The mean concentration of Li in laboratory drinking water was 6.5 ng/mL.

The smallest amounts of Li were found in green tea infusions and the largest ones in red teas infusions. Exclusion of one of the green teas (Green Tea), caused dispersion of results in the infusions of black, green and red teas, is smaller compared to fruit and herbal teas. Of great importance is here certainly the raw material composition of teas and performed production processes. Among tested teas, large amounts of Li were found in the infusions prepared from the rooibos leaves, nettle and horsetail. The content of Li in the group of green teas infusions is statistically significantly different compared to red teas infusions (Kruskal–Wallis test). Such differences are also relevant for red and fruit tea infusions. The average content of Li in the infusions of tea made from the leaves and bags is comparable. Under the conditions of the experiment, taking into account all teas infusions, the pH value does not significantly affect the amount of extracted Li (Spearman's correlation coefficient $r = 0.25$). However, in the group of black teas (pH 6.4–7.2), the correlation is significant and strong ($r = 0.53$), and in the group of herbal teas (pH 6.6–8.3), strong ($r = 0.46$). The pH values of the remaining infusions were as follows: green teas 6.7–7.2, red teas 6.6–7.1 and fruit teas 6.4–7.2. 1 L of tea infusions provide mean 1.5–5.6 μg Li, and together with tap water 8.8–12.1 μg (Fig. 1). Such Li concentration is similar to wine [15]. So, consumption of 1 L of teas infusions can realize a provisional RDA for this element in an amount of about 1 %.

There is a little data on Li content in food products including teas infusions. Gajewska et al. [24] determined Li concentration in green and black teas at the levels of 0.026 ± 0.024 and 0.041 ± 0.040 mg/100 g, respectively. Łozak et al. [25] measured Li content in raw mint leaves 0.515 ± 0.026 and in its infusion 0.339 ± 0.008 mg/kg. The authors stated that 65.8 % of Li is leached from mint leaves and 61.7 % from nettle leaves. Özcan et al.

[26] found Li in amount of 1.24 ± 0.09 ppm in black tea and 1.14 ± 0.12 ppm in green tea. The smaller contents of Li, i.e. <0.08 μg/g in tea leaves (Lipton Yellow Label) and 0.45 μg/L in infusion were described by Ødegård and Lund [27]. In 15 samples of various teas (black, green and oolong), other authors [28] analysed Li in the range of 50–375 ng/g.

Conclusions

Infusions made from the leaves of red teas, rooibos and some herbs provide higher amounts of Li than other tested teas. It seems that some herbal teas may be a better source of Li than traditional green and black teas. Thus, we rather need to undertake research in this area.

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Conflict of interest None.

Compliance with Ethics Requirements This article does not contain any studies with human or animal subjects.

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