Journal of Elementology ISSN 1644-2296

Czernicka M., Zaguła G., Bajcar M., Saletnik B., Puchalski Cz. 2018.
*Assessment of the nutritional value of high quality fruit infusions based on the content of bioelements and toxic metals*.
J. Elem., 23(3): 1057-1072. DOI: 10.5601/jelem.2017.22.4.1551



RECEIVED: 26 October 2017
ACCEPTED: 22 February 2018

**ORIGINAL PAPER**

# ASSESSMENT OF THE NUTRITIONAL VALUE OF HIGH QUALITY FRUIT INFUSIONS BASED ON THE CONTENT OF BIOELEMENTS AND TOXIC METALS*

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## Abstract

Significant growth in the sales of fruit infusions and green teas has been observed in recent years. Different types of fruit infusions vary in terms of the mineral composition, while the content of minerals in infusions also depends on the duration and temperature of brewing. Being uncertain about the composition of fruit teas available on the market, consumers increasingly often look for high quality fruit infusions based exclusively on dried fruit, with no additives and aromas. The study was designed to assess the nutritional value of five types of high quality fruit teas, based on the chemical composition of the dried fruit and the content of minerals and toxic metals in infusions. The research material consisted of 5 high quality fruit teas of different origin purchased in an online store. The study was designed to examine the chemical composition of the dried fruit material (content of water, protein, volatile substances and ash), and the content of selected minerals and toxic metals in brewed fruit infusions. Fine quality fruit teas are characterised by a high content of potassium and sodium. The highest content of minerals was found in hibiscus infusion. Infusions from elderberry and hibiscus fruit may be a valuable source of zinc in a diet. Prolonged brewing of fruit tea resulted in an increased content of all minerals and toxic metals in the infusions, from at least 40% in the case of phosphorus to a 6-fold increase in the content of Mn. No risk of poisoning with toxic metals was shown, not even in the case of frequent consumption of infusions made from high quality fruit teas. Given the beneficial mineral composition of infusions based on the fruit teas in question, particularly hibiscus tea, their daily consumption may significantly improve the body's hydration, mineral content and electrolyte balance.

**Keywords**: fruit teas, bioelements, toxic metals, extracts.

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* Funding: Faculty of Biology and Agriculture potential research 2016, University of Rzeszów.

# INTRODUCTION

As well as being a component of healthy, low-calorie diets followed by a growing number of people, fruit infusions are a healthy alternative to other beverages. The said trend has an impact on the tea market structure. Although the retail trade is still dominated by black teas, which – combined with flavoured teas such as Earl Grey – account for 70% of the related products favoured by consumers, in recent years a significant growth has been observed in the sales of fruit and green teas. This considerably greater interest in teas relates particularly to top quality products, meaning that consumers not only make more informed choices but also have higher expectations regarding the quality of products as well as their functional and nutritional properties. Given the fact that more and more people pay attention to what they eat and drink, a dynamic growth is expected in the near future in the production of herbal, fruit, green and functional teas (Rusinek-Prystupa 2013). Numerous related studies have focused on black, green and red teas, while there is a scarcity of data pertaining to the nutritional properties of infusions based on dried fruit (Szlachta, Małeczka 2008, Sielicka et al. 2010). Compared to traditional tea, fruit infusions are characterised by a lower content of polyphenols and weaker antioxidant properties. However, given the fact that consumers are increasingly interested in such beverages, it is possible that fruit teas could significantly supplement a daily diet with minerals. Owing to their content of antioxidants, dried fruit improve the nutritional properties of fruit teas. Zujko et al. (2011) determined the total content of polyphenols and the antioxidant potential of fruit teas available from retailers (e.g. wild rose, hibiscus and raspberry teas), and reported that wild rose infusions showed the highest antioxidant activity. By properly designing the quantitative and qualitative composition of dried fruit mixes, it is possible to enhance their healthful properties and to produce teas with the best possible sensory qualities (Sikora et al. 2009, Pękal et al. 2011).

Different types of fruit tea vary in terms of mineral composition, while the content of minerals in their infusions also depends on the duration and temperature of brewing. Depending on the type of raw material used, one glass of fruit tea may provide a human body with up to 10% of their daily requirement for such elements as manganese and zinc, while the content of other elements does not exceed 1% of the reference daily intake (Jach 2005).

Brzezicha-Cirocka et al. (2015) investigated people's preferences related to fruit teas and showed that consumers most frequently choose fruit teas in teabags, they tend to drink a minimum of 1-3 cups per day, in all seasons, regularly throughout the year. It is extremely difficult to assess the quality of tea sold in teabags and to make the right choice, therefore one should check the product's composition, particularly the proportional content of dried fruit. A study conducted by Newerli-Guz et al. (2009) showed that most fruit teas were multiple-component products and contained a variety of ingredients, not necessarily of natural origin. Commonly applied technological treatments are designed to enhance their sensory properties, particularly in herbal teas as well as fruit and herbal mixtures, by introducing taste and flavour enhancers as well as additives improving the colour and even health -promoting properties of infusions (NEWERLI-GUZ et al. 2009). Being uncertain about the composition of the fruit teas available on the market, increasingly often consumers look for high quality fruit teas based exclusively on dried fruit, with no additives and aromas.

The study was designed to assess the nutritional value of five types of high quality fruit tea, based on the chemical composition of the dried fruits and the contents of minerals and toxic metals in infusions.

## MATERIAL AND METHODS

The research material included 5 high quality fruit teas of different origin, two were imported into Poland, and all were purchased in an online store. Table 1 contains the distributors' information about the products.

Table 1

Brewing parameters recommended by the distributors of the products

| Origin | Name of product | Brewing parameters | | |
|---|---|---|---|---|
| | | proportion | temp. (°C) | time (min) |
| Poland | Chokeberry | 6 g 250 $ml^{-1}$ | 100 | 5 |
| Poland | Elderberry | 6 g 250 $ml^{-1}$ | | 15-20 |
| China | Goji Berry | 3 g 150 $ml^{-1}$ | 95 | 5-8 |
| Nigeria | Hibiscus | 3 g 150 $ml^{-1}$ | 100 | 5 |
| Poland | Wild Rose | 5 g 250 $ml^{-1}$ | | 10-15 |

The study assessed both dried products and aqueous infusions of fruit teas prepared in standard laboratory conditions. The chemical composition, such as the water, volatiles and ash content of dried fruit teas, was determined with the use of a TGA701 analyser manufactured by LECO. For this purpose, tea samples were homogenised in a Basic Analytical Mill, Type A11, manufactured by IKA, and then prepared for thermogravimetric examination in accordance with the standard (PN-ISO 1573:1996).

In order to determine the water content, 2 g samples of the material were placed in crucibles and subjected to continuous drying at 103°C until constant mass was reached with differences of less than 0.05% during consecutive weight measurements (PN-ISO 1573:1996). The ash content was determined taking into account the difference between the initial mass of the material (approx. 2 g) and the weight of the sample after incineration at 550°C in a nitrogen atmosphere. The content of volatile compounds in dried fruit tea was determined by incinerating samples placed in covered crucibles at 950°C for a duration of 20 minutes from the moment the critical temperature was reached (PN-ISO 1575:1996). The content of protein in dry homogenised samples was determined with the use of an element analyser TrueSpec Leco CHNS, and the total protein content was calculated with the use of an adequate multiplier (6.25). All the analyses were replicated three times.

Fruit tea infusions were prepared in conical flasks by pouring 100 ml of demineralised water brough to the temperature of 100°C over 1 g of dried fruit tea. Deionised water was obtained using a HLP 5P deioniser manufactured by Hydrolab Poland. The mixture was covered and brewed for 5, 15 and 30 minutes. After the set time, the infusions were trickled through filter paper into measuring flasks and left to cool down. Before analysis, the samples were filtered through MCE membrane filters with pores 0.45 μm in diameter and diluted 4 times. Assessment of selected minerals, such as Na, K, P, Mn, Ca, Cu, Zn, Al, and the toxic metals Cd, Pb in infusions prepared in various conditions were determined by optical emission spectrometry with inductively-induced plasma (ICP-OES) using a Thermo iCAP 6500 spectrophotometer (Thermo Fisher Scientific Inc., USA). The detection limit for each element was determined at a level which was not lower than 1 μg $L^{-1}$. A curve fit factor for the elements studied was above 0.99. All the analyses were made in three independent replications for each sample. The targeted repeatability expressed as the relative standard deviation (RSD) and targeted recovery were 92% to 106%, respectively. The method was validated using certified reference material (INCT-TL-1 tea leaves and NIES CRM No. 7 Tea Leaves). The response from the equipment was periodically checked with known standards. In order to identify the relevant measurement lines and avoid possible interferences, the method of adding an internal standard was applied. Yttrium and ytterbium ions were used as internal standards.

All parts of the experiment were carried out in three independent replications. The findings obtained were subjected to statistical analyses with the use of Statistica ver. 10.0. The results were analysed statistically with multi-way ANOVA and differences between means were assessed with the Duncan test.

## RESULT AND DISCUSSION

In the present study, the mean values of the parameters describing the examined products have confirmed big differences between the selected kinds of teas. The specific values of physicochemical parameters do not explicitly classify the tea brands in terms of properties typical for each type; hence it is impossible to define uniform characteristics of a selected type. Table 2 presents the mean results of chemical composition analyses of the selected types of fruit tea.

Table 2

Chemical composition of fruit teas (mean values ± SD)

| No. | Type of tea | Water | Ash | Volatiles | Protein |
|---|---|---|---|---|---|
| | | (%) | | | |
| 1 | Chokeberry | $8.53^{b} \pm 0.06$ | $4.32^{a} \pm 0.08$ | $2.02^{b} \pm 0.18$ | $4.41^{b} \pm 1.08$ |
| 2 | Elderberry | $13.14^{e} \pm 0.04$ | $5.74^{b} \pm 0.05$ | $2.04^{b} \pm 0.08$ | $13.98^{e} \pm 0.38$ |
| 3 | Goji Berry | $12.30^{d} \pm 0.05$ | $5.67^{b} \pm 0.03$ | $2.35^{c} \pm 0.14$ | $11.35^{d} \pm 0.65$ |
| 4 | Hibiscus | $9.29^{c} \pm 0.13$ | $9.43^{d} \pm 0.10$ | $1.89^{ab} \pm 0.09$ | $7.81^{c} \pm 0.88$ |
| 5 | Wild Rose | $5.33^{a} \pm 0.11$ | $8.30^{c} \pm 0.20$ | $2.58^{d} \pm 0.12$ | $2.35^{a} \pm 0.68$ |

According to the Duncan's test, means denoted with the same letter are not significantly different at $\alpha \leq 0.05$.

Out of all the fruit teas subjected to research, the highest content of water and protein was found in dried Elderberry and Goji Berry teas, and the lowest one was in Wild Rose tea. Wild Rose and Hibiscus tea had the largest amounts of ash. Furthermore, infusions based on Wild Rose and Goji Berry tea had the highest content of volatiles, and the lowest amount of these compounds was identified in Hibiscus tea. For the purpose of our analysis, it should be pointed out that among the five fruit teas analysed dried it was Hibiscus tea that contained mostly leaves and flowers, while and the remaining mixes consisted mainly of berries and fruit, either whole or fragmented. It can be assumed that the degree of fragmentation and the structure of dried teas affected the process of extracting the minerals in the course of brewing. Tables 3, 4, 5, 6, 7 show the mean results in relation to the selected minerals contained in the infusions prepared in various conditions, according to the objectives of the research hypothesis, and these findings suggest that the selected types of fruit tea differ substantially. Table 8 presents the effects of tea type and brewing time on the content of minerals and toxic metals in fruit tea infusions.

It is impossible to define uniform health-related characteristics of each tea. However, it is possible to identify, within each group, the products with the most beneficial content of minerals. Table 8 presents statistically significant differences between means of minerals and toxic metals in different type of tea and depending on the extraction time.

Effect of tea type and brewing time on mineral and toxic metal content in a serving (200 ml) of high quality fruit teas extracts.

Statistical analysis confirmed highly significant differences in the content of all minerals and toxic metals between particular types of fruit tea. In the analysis of the impact of a type of tea, highly significant differences were observed in terms of the content of K, Mn, Ca, Cu, Zn, and also Al and Cd between Hibiscus Tea and the other tea types. Another type of the fruit tea which showed highly significant differences was Wild Rose Tea, especially in the case of a K, P, Mn, Ca, and Pb. Statistically significant differences were observed in the content of Al between Elderberry tea infusions in com-

Table 3

The content of elements and toxic metals in Chokeberry tea extracts (mean value ± SD)

| Extracting time (min) | Na | K | P | Mn | Ca | Cu | Zn | Al | Cd | Pb |
|---|---|---|---|---|---|---|---|---|---|---|
| | (mg $L^{-1}$) | | | | | | | | (μg $L^{-1}$) | |
| 5 | $9.33^{a} \pm 0.02$ | $48.96^{a} \pm 0.01$ | $0.56^{a} \pm 0.05$ | $0.12^{a} \pm 0.01$ | $3.02^{a} \pm 0.01$ | $0.02^{a} \pm 0.01$ | $0.15^{a} \pm 0.05$ | nd | nd | nd |
| 15 | $9.40^{a} \pm 0.04$ | $74.16^{b} \pm 0.06$ | $0.91^{b} \pm 0.01$ | $0.15^{b} \pm 0.03$ | $3.08^{a} \pm 0.01$ | $0.03^{a} \pm 0.02$ | $0.23^{b} \pm 0.05$ | nd | nd | $2.00^{a} \pm 0.50$ |
| 30 | $10.37^{b} \pm 0.02$ | $107.36^{c} \pm 0.00$ | $1.37^{c} \pm 0.06$ | $0.15^{b} \pm 0.02$ | $3.16^{b} \pm 0.01$ | $0.06^{a} \pm 0.02$ | $0.24^{b} \pm 0.05$ | nd | nd | $4.00^{b} \pm 0.25$ |

According to the Duncan's test, means denoted with the same letter are not significantly different at $\alpha \leq 0.05$;
nd – not detected

Table 4

The content of elements and toxic metals in Elderberry tea infusions (mean value ± SD)

| Extracting time (min) | Na | K | P | Mn | Ca | Cu | Zn | Al | Cd | Pb |
|---|---|---|---|---|---|---|---|---|---|---|
| | (mg $L^{-1}$) | | | | | | | | (μg $L^{-1}$) | |
| 5 | $13.81^{a} \pm 0.02$ | $292.00^{a} \pm 0.01$ | $4.99^{a} \pm 0.05$ | $0.37^{a} \pm 0.00$ | $5.56^{a} \pm 0.01$ | $0.06^{a} \pm 0.04$ | $0.88^{a} \pm 0.05$ | $0.08^{a} \pm 0.02$ | nd | nd |
| 15 | $15.21^{b} \pm 0.02$ | $368.00^{b} \pm 0.04$ | $5.31^{b} \pm 0.05$ | $0.43^{ab} \pm 0.03$ | $6.52^{b} \pm 0.01$ | $0.06^{a} \pm 0.05$ | $1.17^{b} \pm 0.04$ | $0.10^{a} \pm 0.02$ | nd | $1.00^{a} \pm 0.20$ |
| 30 | $22.01^{c} \pm 0.03$ | $431.20^{c} \pm 0.02$ | $6.91^{c} \pm 0.05$ | $0.51^{b} \pm 0.03$ | $7.52^{c} \pm 0.01$ | $0.07^{a} \pm 0.04$ | $1.68^{c} \pm 0.02$ | $0.16^{b} \pm 0.04$ | nd | $3.00^{b} \pm 0.50$ |

Explanation see Table 3

Table 5

The content of elements and toxic metals in Goji Berry tea infusions (mean value ± SD)

| Extracting time (min) | Na | K | P | Mn | Ca | Cu | Zn | Al | Cd | Pb |
|---|---|---|---|---|---|---|---|---|---|---|
| | (mg L$^{-1}$) | | | | | | | | μg L$^{-1}$ | |
| 5 | $71.81^{a} \pm 0.02$ | $205.60^{a} \pm 0.02$ | $2.27^{a} \pm 0.05$ | $0.19^{a} \pm 0.01$ | $3.24^{a} \pm 0.01$ | $0.07^{a} \pm 0.02$ | $0.40^{a} \pm 0.05$ | $0.04^{a} \pm 0.02$ | nd | nd |
| 15 | $100.60^{b} \pm 0.04$ | $228.80^{b} \pm 0.02$ | $2.99^{b} \pm 0.06$ | $0.23^{ab} \pm 0.04$ | $4.11^{b} \pm 0.03$ | $0.08^{a} \pm 0.00$ | $0.48^{a} \pm 0.03$ | $0.05^{a} \pm 0.02$ | $3.00^{a} \pm 0.50$ | $1.00^{a} \pm 0.25$ |
| 30 | $213.80^{c} \pm 0.02$ | $268.20^{c} \pm 0.04$ | $3.15^{b} \pm 0.05$ | $0.26^{b} \pm 0.02$ | $4.89^{c} \pm 0.06$ | $0.11^{a} \pm 0.04$ | $0.96^{b} \pm 0.05$ | $0.14^{b} \pm 0.04$ | $4.00^{b} \pm 0.75$ | $4.00^{b} \pm 0.50$ |

Explanation see Table 3

Table 6

The content of elements and toxic metals in Hibiscus tea infusions (mean value ± SD)

| Extracting time (min) | Na | K | P | Mn | Ca | Cu | Zn | Al | Cd | Pb |
|---|---|---|---|---|---|---|---|---|---|---|
| | (mg L$^{-1}$) | | | | | | | | (μg L$^{-1}$) | |
| 5 | $12.21^{a} \pm 0.02$ | $409.60^{a} \pm 0.02$ | $2.83^{a} \pm 0.05$ | $1.42^{a} \pm 0.02$ | $18.60^{a} \pm 0.01$ | $0.10^{a} \pm 0.02$ | $0.80^{a} \pm 0.05$ | $0.30^{a} \pm 0.02$ | nd | nd |
| 15 | $13.41^{b} \pm 0.01$ | $512.00^{b} \pm 0.04$ | $3.15^{b} \pm 0.05$ | $1.73^{b} \pm 0.05$ | $25.56^{b} \pm 0.01$ | $0.12^{ab} \pm 0.04$ | $1.36^{b} \pm 0.06$ | $0.49^{b} \pm 0.01$ | $4.00^{a} \pm 0.50$ | $3.00^{a} \pm 0.50$ |
| 30 | $16.61^{c} \pm 0.03$ | $712.00^{c} \pm 0.06$ | $3.31^{b} \pm 0.03$ | $1.99^{c} \pm 0.08$ | $29.26^{c} \pm 0.02$ | $0.16^{b} \pm 0.01$ | $2.24^{c} \pm 0.04$ | $0.64^{b} \pm 0.04$ | $6.00^{b} \pm 0.50$ | $8.00^{b} \pm 1.00$ |

Explanation see Table 3

Table 7

The content of elements and toxic metals in Wild Rose tea infusions (mean value ± SD)

| Extracting time (min) | Na | K | P | Mn | Ca | Cu | Zn | Al | Cd | Pb |
|---|---|---|---|---|---|---|---|---|---|---|
| | (mg L$^{-1}$) | | | | | | | | (µg L$^{-1}$) | |
| 5 | 12.37$^{a}$ ± 0.02 | 372.00$^{a}$ ± 0.00 | 2.75$^{a}$ ± 0.05 | 0.51$^{a}$ ± 0.00 | 8.18$^{a}$ ± 0.01 | 0.05$^{a}$ ± 0.01 | 0.39$^{a}$ ± 0.05 | 0.06$^{a}$ ± 0.04 | nd | nd |
| 15 | 12.37$^{a}$ ± 0.04 | 383.20$^{a}$ ± 0.04 | 4.51$^{b}$ ± 0.04 | 0.62$^{b}$ ± 0.03 | 8.60$^{a}$ ± 0.02 | 0.07$^{a}$ ± 0.02 | 0.44$^{a}$ ± 0.06 | 0.07$^{a}$ ± 0.02 | nd | 5.00$^{a}$ ± 0.75 |
| 30 | 19.33$^{b}$ ± 0.02 | 470.40$^{b}$ ± 0.05 | 4.57$^{b}$ ± 0.05 | 0.69$^{b}$ ± 0.04 | 11.80$^{b}$ ± 0.02 | 0.07$^{a}$ ± 0.05 | 0.96$^{b}$ ± 0.03 | 0.09$^{a}$ ± 0.04 | 2.00 ± 0.25 | 8.00$^{b}$ ± 0.50 |

Explanation see Table 3

Table 8

Effect of tea type and brewing time on mineral and toxic metal content in a serving (200 ml) of high quality fruit teas extracts

| Elements | | Type of tea | | | | | Brewing time (min) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Chokeberry | Elderberry | Goji Berry | Hibiscus | Wild Rose | 5 | 15 | 30 |
| (mg) | Na | 1.943$^{\text{HMOR}}$ | 3.520$^{\text{BIKŁ}}$ | 26.204$^{\text{ACEG}}$ | 2.846$^{\text{FLP}}$ | 2.987$^{\text{DJN}}$ | 6.150$^{DF}$ | 8.107$^{BE}$ | 11.491$^{AC}$ |
| | K | 15,938$^{\text{HMRT}}$ | 73.831$^{\text{DJNP}}$ | 47.258$^{\text{FLOS}}$ | 109.318$^{\text{ACEG}}$ | 82.409$^{\text{BIKŁ}}$ | 53.680$^{DF}$ | 63.172$^{BE}$ | 80.382$^{AC}$ |
| | P | 0.192$^{\text{HMRT}}$ | 1.154$^{\text{ACEG}}$ | 0.572$^{\text{FLOS}}$ | 0.625$^{\text{DJNP}}$ | 0.796$^{\text{BIKŁ}}$ | 0.551$^{DF}$ | 0.674$^{BE}$ | 0.778$^{AC}$ |
| | Mn | 0.029$^{\text{HMRT}}$ | 0.088$^{\text{DJNP}}$ | 0.045$^{\text{FLOS}}$ | 0.348$^{\text{ACEG}}$ | 0.122$^{\text{BIKŁ}}$ | 0.107$^{DF}$ | 0.127$^{BE}$ | 0.144$^{AC}$ |
| | Ca | 0.624$^{\text{HMRT}}$ | 1.312$^{\text{DJNP}}$ | 0.823$^{\text{FLOS}}$ | 5.045$^{\text{ACEG}}$ | 1.917$^{\text{BIKŁ}}$ | 1.555$^{DF}$ | 1.949$^{BE}$ | 2.328$^{AC}$ |
| | Cu | 0.003$^{\text{HMO}}$ | 0.013$^{\text{FLN}}$ | 0.018$^{\text{BIKŁ}}$ | 0.026$^{\text{ACEG}}$ | 0.014$^{\text{DJN}}$ | 0.011$^{DF}$ | 0.015$^{BE}$ | 0.018$^{AC}$ |
| | Zn | 0.043$^{\text{HMOR}}$ | 0.252$^{\text{BIKŁ}}$ | 0.122$^{\text{FLP}}$ | 0.292$^{\text{ACEG}}$ | 0.124$^{\text{DJN}}$ | 0.105$^{DF}$ | 0.151$^{BE}$ | 0.244$^{AC}$ |
| | Al | nd | 0.024$^{\text{Bac}}$ | 0.015$^{\text{Fd}}$ | 0.096$^{\text{ACE}}$ | 0.016$^{\text{Db}}$ | 0.019 | 0.028 | 0.043 |
| (µg) | Cd | nd | nd | 0.492$^{\text{BE}}$ | 0.722$^{\text{AC}}$ | 0.150$^{\text{DF}}$ | nd | 0.242 | 0.491 |
| | Pb | 0.401$^{\text{BHac}}$ | 0.287$^{\text{FLd}}$ | 0.364$^{\text{DJb}}$ | 0.822$^{\text{GIK}}$ | 0.873$^{\text{ACE}}$ | nd | 0.506$^{B}$ | 1.086$^{A}$ |

Statistically significant differences between means ($^{A\text{-}S}$ for $p \leq 0,01$; $^{a\text{-}d}$ for $p \leq 0,05$), marked by different letters in the rows.

parison with the Wild Rose and Goji Berry tea infusions and also in the content of Pb of Goji Berry and Elderberry tea infusions. The analysis of the impact of brewing time as a factor improving extraction of minerals in fruit tea infusions showed highly significant statistical differences in all cases. During the 30 min of extraction, the highest increase in concentration was observed for sodium (up to 87%) and copper (about 63%). The potassium and calcium content increased by about 50%, and while that of zinc, manganese and phosphorus rose by 32-41%. The analysis of changes in the toxic metal content showed a statistically significant high content of lead content between 15 and 30 min of breweing, which on average increased by 113%. This was probably due to the increased moisture content of the tea components due to their prolonged contact with the extractant, especially when a tea mix was composed of slightly shredded or dry whole fruit, most often attributed to the presence of toxic metals. This finding can be considered as a suggestion how to prepare healthier fruit tea infusions.

The analysis of the elements in infusions of the selected fruit teas showed the predominance of potassium in all types of tea, with the highest concentration in Hibiscus tea and lowest in Chokeberry tea. Another mineral identified in the fruit tea infusions in quantities significantly exceeding the concentrations of the remaining elements was sodium; its highest amount of approximately 213 mg $L^{-1}$ was found in the Goji Berry infusion after brewing for 30 min, while the concentration of sodium in the remaining infusions was on average 8-10 times lower. Sodium and potassium are the two most important elements enabling the body to maintain the right balance of electrolytes. The main dietary sources of sodium include table salt as well as the sodium chloride present in such foods as cereals and meat products. On the other hand, potassium is present in almost all food products, especially in nuts, seeds, cocoa, chocolate, vegetables and fruit; significant quantities also occur in meat and in cereals, and particularly good sources of this element include dried fruit (Jarosz 2012). The content of minerals determined in the tea infusions suggests that dried Goji Berry tea contained a significant proportion of dried fruit. The recommended intake of these two minerals depends on such factors as age, sex, physiological condition, ambient temperature as well as physical activity and treatment with diuretic medication. In order to maintain the right balance of electrolytes and acid-alkaline equilibrium, and to ensure proper functioning of the nervous and muscular systems, in addition to providing adequate water intake it is necessary to ensure a proper mineral composition of the fluids, which should contain sodium and potassium in particular (American Norms 2004, 2011). In view of the above recommendations, by being natural electrolytes the fruit tea infusions examined here are a valuable component of the diet. In the light of the nutritional requirements such as the recommended intake of sodium (1500 mg) and potassium (4700 mg) defined for adults by experts of the FAO/WHO (World Health Organization 2003), consumption of 4 glasses of fine-quality Goji Berry tea may satisfy 15% of the daily requirement for the former element. In the case of potassium, approximately 4 glasses of Hibiscus tea or 6 glasses of Wild Rose tea provide 15% of the recommended daily intake. The lowest concentrations of all the minerals were identified in the Chokeberry tea infusions, although it needs to be added that the fruit from this plant is most valuable from the dietary viewpoint owing to its high polyphenol content (Bermúdez-Soto et al. 2007).

On the other hand, daily consumption of 5 cups of Hibiscus tea or 7 cups of Elderberry tea may completely cover the Recommended Dietary Allowances (RDA) for Zn, defined at 11 mg for males and at 8 mg for females (World Health Organization 2003, Deshpande et al. 2013).

Powell et al. 1998 examined the bioavailability of minerals in simulated intestinal conditions and found the bioavailability of manganese at a level of approximately 40%, and in the bioavailability of Zn extracted from wild rose tea was twice as high as that of Mn.

Brzezicha-Cirocka et al. (2015) examined the mineral composition of fruit tea infusions and established that the predominant element in these teas was manganese, on average at a level of 13-77 mg 100 $g^{-1}$ of dry tea, therefore 200 ml of the fruit tea infusion could satisfy 15% and 12% of daily requirement for Mn in females and males, respectively, which is consistent with the present findings. In the present study, a similar result was obtained in the case of Hibiscus tea infusions, while a cup of Wild rose tea may satisfy 6-8% of the daily requirement for Mn on average. Out of all the infusions in question, Hibiscus tea had the highest concentrations of all the minerals except for Na and P. Elderberry infusions were identified as the best source of phosphorus. Because of the high content of Cu in Hibiscus tea, 4 cups of this infusion may satisfy up to 20% of the daily requirement for this element. It was also established that concentrations of all minerals, including toxic metals, increased in the tea infusions during a 30-minute brewing process. The longer duration of brewing recommended by the distributor of the fruit teas (in the case of Elderberry and Wild Rose even 15-20 min, (Table 1) may have been linked to the structure of the dried tea consisting of coarsely fragmented and complete dried fruit requiring deeper penetration of the extracting agent. It would seem that a longer brewing time leads to more effective extraction of minerals and other nutritional and functional components. Yet, this does not always happen, because the higher temperature may destroy and deactivate such sensitive components as antioxidants or vitamins. Furthermore, the present study also suggests that during a long-lasting brewing process, undesirable elements, e.g. toxic metals, leach into the infusion. Issues related to toxic metals occurring in dried tea leaves and *Camelia sinesis* infusions have been explored by numerous researchers (Horie, Kohata 2000, Shen, Chen 2008). Much attention has also been paid to aluminium, which is necessary for health, yet in specific conditions (low pH) it may accumulate in the body, producing toxic effects. Authors of studies focusing on harmful elements in infusions based on flavoured and scented teas have frequently pointed out that the fruit components present in such mixtures are the main source of toxicity (Winiarska-Mieczana et al. 2011, Michalak-Majewska 2013). Because of this, the present study examined high quality fruit teas consisting mainly of dried fruit and herbs (Hibiscus), also commonly found in popular teas available from retailers. The recommendations specified by world communities and organisations dealing with food safety (The Joint Food and Agriculture Organization/World Health Organization Expert Committee on Food Additives) suggest that in the case of Al the Provisional Tolerable Weekly Intake amounts to 2 mg $kg^{-1}$ of body mass (Yang et al. 2014). Based on the present findings related to the contents of aluminium in fruit tea infusions it can be concluded that daily consumption of one glass of Hibiscus tea infusion, which has the highest contents of Al, at a level of 0.16 mg per 250 ml, accounts for less than 1% of the daily intake recommended for an individual with a body mass of 70 kg. In the case of the maximum extraction from all the fruit teas, i.e. following a 30-minute brewing process, a 200 ml cup was found to contain on average about 0.02% of tolerable daily Al intake from food. On the other hand the respective PTWI limits for cadmium and lead are 7 µg and 25 µg $kg^{-1}$ of body mass (Evaluation of Certain Food Additives and Contaminants 2000, 2004.). In view of the above recommendations, the daily intake of Cd and Pb with food, defined for an individual with body mass of 70 kg, should not on average exceed 70 µg and 250 µg, respectively. Daily consumption of 4 cups of Hibiscus tea infusion would be equivalent to about 4% of the PTWI defined for Cd, on the other hand the content of this element in 4 cups of Goji Berry tea infusion is equivalent to about 2.9% of the tolerable daily intake of Cd; this means that the consumption of 100 cups of Hibiscus tea or 138 cups of Goji Berry tea could result in exceeding the norm for Cd intake. To exceed the daily intake of Pb one would have to consume 285 cups of 200 ml of Wild Rose tea or 124 cups of Hibiscus tea. As for infusions made by 30-minute brewing, consumption of 230 cups may pose a health hazard due to the concentration of Pb in the fruit teas.

It is likely that longer tea brewing contributes to an improved effectiveness of extraction by enabling the release of minerals from cellular structures of the plant components present in dry tea leaves, in accordance with the law of diffusion, i.e. elements spontaneously move from one phase of the system into the second phase. The process of extracting mineral components also depends on the size of the mass exchange surface, i.e. the level of ingredient fragmentation as well as the solubility of minerals in an aqueous environment. A longer duration of extraction favourably affects the degree of wetting of the material subjected to extraction as well as its deep penetration (Karak, Bhagat 2010). Natesan and Ranganathan (1990) found a positive correlation between the contents of selected elements in tea infusions and the time of brewing. Seenivasan et al. (2008) showed a 10-fold increase in the concentration of some elements in tea infusions as a result of 6-minute brewing.

Winiarska-Mleczana et al. (2011) reported that cadmium and lead were present in therapeutic herbal tea mixtures. Their study showed that the level of toxic metal extraction into aquatic solution was high; in the case of cadmium the mean result was 44.13%, and for lead it amounted to 53.16%, while the intake of cadmium and lead in the course of therapies based on the herbal teas accounted for 0.34% of the PTWI for cadmium and 0.42% of the PTWI for lead. On the other hand, the fruit teas examined by Wojciechowska-Mazurek et al. (2010) on average contained 0.37 mg $kg^{-1}$ of lead. Długaszek and Kwapis (2005) examined infusions from black, green, fruit and herbal teas for the content of various metals relative to the pH of the aqueous solution. The infusions were found to contain 0.05 - 0.33 μg $g^{-1}$ of Pb and 0.005 - 0.056 μg $g^{-1}$ of Cd. It was also observed that a change in pH of the solution affected the migration of metals, with increased acidity leading to significantly higher extraction. Acidification of the infusions with lemon juice or citric acid resulted in increased Pb and Cd content in the infusion. Other researchers have shown that the toxicity of trace elements not only depends on their concentration, but also on their speciation (Erdemoğlu et al. 2000). Similar issues were investigated by Street et al. (2007), who examined various tea infusions for their total Al content. Their study showed that Al speciation in tea infusions was not affected either by increased extraction time accompanied with no additives or by the addition of sugar. After lemon juice was added, speciation of Al changed in one sample of black tea and five samples of green tea in their experiment. These findings suggest that lemon juice as an additive can significantly influence Al speciation in tea infusions. The relative distribution of Al between its various organic and inorganic complexes influences its mobility in the environment, bioavailability and toxicity. The presence of fluoride, phosphate and organic compounds, which can form complexes with aluminium, results in a decrease of its toxicity.

The knowledge of the presence of some selected trace elements in tea leaves and tea infusions, based on the available literature, suggested that the presence of trace elements in green tea is lower than in black tea in most cases. Determination of Cu performed by Tautkus et al. (2004) in several commercially available black and green tea samples showed the concentration of Cu in these tea samples ranged from 19.8 mg $kg^{-1}$ in green tea to 33.9 mg $kg^{-1}$ in black tea infusions. Mehra and Baker (2007) showed that availability of Cu from drinking 1 L of tea per day provides 2.88% (loose tea) and 2.39% (tea bag) of the average daily dietary intake.

According to the literature data, Mn is the only element with a significant dietary amount in tea, especially in black tea (Street et al. 2007). Mehra and Baker (2007) concluded that the percentage of Mn transfer in green teas was lower than in black teas at all infusion times. Pohl and Prusisz (2007) analyzed three black tea and green tea samples each for the Mn concentration in infusions available in Poland and the results showed that 1.56 to 6.02 mg $L^{-1}$ and 1.53 to 2.02 mg $L^{-1}$ Mn was available in black and green tea infusion, respectively.

Karimi et al. (2008) reported the content of 0.035 mg Al $L^{-1}$ in tea infusion from black tea marketed in Mashhadmarket, Iran. The results of analysis described by Ansari et. al (2007) showed that the mean level of Al was 699.2 ± 172.7 mg $kg^{-1}$ for Iranian and 388.3 ± 98.3 mg $kg^{-1}$ for imported black tea and the values for Cd, Pb, and were non-detectable. In another study, a total of 29 tea samples of different origin, 13 green tea samples, 13 black tea samples, two semi-fermented and one white tea, imported from the Czech Republic, were collected and analyzed for total content of Al in tea infusions (Street et al. 2007). It was revealed that the average Al content in black tea was 1070 mg $kg^{-1}$ whereas, in green tea it was 1340 mg $kg^{-1}$. According to Mehra and Baker (2007), 1 L of tea can provide more than 100% of the daily dietary intake of Al, although the percentage available for absorption in the intestine is only between 4.96% and 9.13% for different tea samples.

On the basis of the existing literature data, it was concluded that Cd in tea infusion was generally low. Shen and Chen (2008) reported that only 52.8% of the total Cd was released from eighteen samples of oolong tea (0.005 μg 100 $mL^{-1}$), 40.3% from fifteen black tea samples (0.06 μg 100 $mL^{-1}$), while no Cd was extracted from fifteen green tea samples in Taiwan. Shokrzadeh et al. (2008) analyzed 10 black tea samples and their result showed that Cd level in Iranian and foreign tea infusions were from below the detectable limit to 1.093 mg $L^{-1}$ and from below the detectable limit to 0.673 mg $L^{-1}$, respectively.

A study carried out by Rutkowska et al. (2012) showed that Rugosa rose fruits are a valuable raw material in the food industry, for instance as a component of dried products. According to these authors, the quality of dried fruit largely depends on the drying method, which only mildly affects its chemical composition; on the other hand, the drying process significantly improves the extraction process in the course of preparing infusions, extracts and solutions based on dried Rugosa rose fruits. Similar conclusions were reported by Bober and Oszmiański (2004), who investigated the usefulness of chokeberry pomace in the production of fruit teas. They also showed that the traditional convection drying method applied at high temperatures adversely affects the colour of infusions, and consequently the usefulness of the dry product in tea production; therefore, other more advanced methods such as microwave drying or lyophilisation are recommended.

Given the fact that caffeine concentrations in most fruit teas are significantly lower than in black or green teas, and that they contain polyphenol antioxidants, valuable minerals, as well as a wide assortment of aromatic compounds which may produce a tranquilising effect, they should be very popular, especially among hard-working people and those suffering from fatigue because, in addition to mental relaxation, such beverages may improve body hydration, mineral content and the electrolyte balance.

## CONCLUSION

As indicated by our analysis, high quality fruit teas are characterised by high content of potassium and sodium. The highest content of minerals was found in Hibiscus tea infusion. It was found that infusions of Elderberry tea and Hibiscus tea may be a valuable source of zinc in a diet. Extended duration of brewing fruit tea resulted in an increased content of all minerals and toxic metals in tea infusions, from at least 40% in the case of phosphorus to a 6-fold increase in the content of Mn. The findings show no risk of poisoning with toxic metals, even in the case of frequent consumption of infusions based on high quality fruit teas.

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