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ORIGINAL ARTICLE

# STUDY OF NUTRITIONAL VALUE OF DRIED TEA LEAVES AND INFUSIONS OF BLACK, GREEN AND WHITE TEAS FROM CHINESE PLANTATIONS

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## ABSTRACT

**Background.** The processing of tea leaves determines the contents of bioactive ingredients, hence it should be expected that each variety of tea, black, red or green, will represent a different package of compounds of physiological importance. Taste and aroma, as well as price and brand are the main factors impacting consumers' preferences with regard to tea of their choice; on the other hand consumers less frequently pay attention to the chemical composition and nutritional value of tea.

**Objective**. The purpose of the study was assessment of the nutritional value of black, green and white high-quality tea leaf from Chinese plantations based on the chemical composition of the dried leaves as well as minerals and caffeine content in tea infusions.

**Material and methods**. The research material included 18 high-quality loose-leaf teas produced at Chinese plantations, imported to Poland, and purchased in an online store. The analyses included examination of the dried tea leaves for their chemical composition (contents of water, protein, volatile substances and ash) and assessment of selected minerals and caffeine contents in the tea infusions.

**Results.** High-quality Chinese green teas were found with the most valuable composition of minerals, i.e. the highest contents of Zn, Mn, Mg, K, Ca and Al and the highest contents of protein in comparison to the other products. Chinese black teas had the highest contents of total ash and caffeine and white teas were characterized with high content of volatile substances, similar to the black teas, and the highest content of water and the lowest content of total ash.

**Conclusions.** The three types of tea brews examined in the present study, in particular green tea beverages, significantly enhance the organism's mineral balance by providing valuable elements.

**Key words:** *tea infusion, caffeine, mineral components, HPLC, ICP-OES*

## STRESZCZENIE

**Wprowadzenie.** Proces przetwarzania liści herbaty ma decydujący wpływ na zawartość składników bioaktywnych, zatem należy oczekiwać, że każdy rodzaj herbat, czarne, czerwone, zielone będzie reprezentował inny pakiet związków o znaczeniu fizjologicznym. Walory smakowe, cena oraz marka to główne czynniki kształtujące preferencje konsumenckie w kwestii wyboru herbaty, rzadziej jednak konsumenci zwracają uwagę również na skład chemiczny i właściwości zdrowotne.

**Cel badań.** Celem badań była ocena wartości odżywczej czarnych, zielonych i białych wysokogatunkowych herbat liściastych z chińskich plantacji na podstawie składu chemicznego suszu a także zawartości minerałów i kofeiny w naparach herbat.

**Materiał i metody.** Materiałem badawczym było 18 wysokogatunkowych, liściastych pochodzących z plantacji chińskich, importowanych do Polski, zakupionych w sklepie internetowym. Zakres analiz obejmował badania składu chemicznego suszu herbacianego (zawartość wody, białka, substancji lotnych i popiołu) oraz analizę zawartość wybranych składników mineralnych i kofeiny w przyrządzonych naparach herbacianych.

**Wyniki.** Wysokogatunkowe chińskie herbaty zielone były produktami o najcenniejszym składzie mineralnym dotyczącym najwyższej zawartości Zn, Mn, Mg, K, Ca oraz Al i najwyższej zawartości białka spośród badanych produktów. Chińskie herbaty czarne wyróżniały się w zakresie najwyżej zawartości popiołu oraz kofeiny a herbaty białe charakteryzowały wysoką zawartością substancji lotnych podobnie jak herbaty czarne oraz najwyższą zawartością wody i najniższą zawartością popiołu ogólnego.

**Wnioski.** Analizowane napary z trzech typów herbat, zwłaszcza herbat zielonych, w znacznym stopniu dostarczają organizmowi cennych pierwiastków.

**Słowa kluczowe:** *napary herbat, kofeina, składniki mineralne, HPLC, ICP-OES*

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## INTRODUCTION

Available in a few varieties, and hundreds of brands, and second only to water, tea is the most popular drink whose consumption is not subject to any limitations due to age or physiological condition. The origins of the aromatic infusions with fine colours are linked with two species of tea shrub representing the family of Theaceae, i.e. *Camellia sinensis* and *Camellia assamica*, whose leaves, plucked at different stages of their development, constitute the basic raw material for the production of dried tea. The finest tea brands are grown in uplands, and the mountainous air additionally contributes to their unique aroma and flavour. Further processing of the leaves depends on the type of tea and the required quality of the final product. In the case of high-quality teas, most technological treatments are performed manually and the harvested parts of plants include young shoots and buds, delicate stalks and first leaflets of tree shrubs [20].

The processing of tea leaves determines the contents of bioactive ingredients, hence it should be expected that each variety of tea, black, red or green, will represent a different package of compounds of physiological importance. Freshly brewed aqueous solutions obtained from dried leaves of *Camelia sinensis* contain a mixture of approx. 300 compounds which are responsible for the characteristic properties and taste of teas [1].

Taste and aroma, as well as price and brand are the main factors impacting consumers' preferences with regard to tea of their choice; on the other hand consumers less frequently pay attention to the chemical composition and nutritional value of tea. In Poland black teas are most popular, yet, as it was shown by a report [12], green teas are more and more often bought because of their fine taste and beneficial health effects. White teas, obtained from young buds and undeveloped leaves, are the most exclusive, refined and expensive group of products, therefore they are not easily available or popular in Poland [14].

In terms of chemical composition teas contain tannin substances, flavonols, proteins and amino acids, aroma producing volatile substances, enzymes, vitamins, mineral compounds and microelements as well as alkaloids [2, 7]. The importance of tea beverages in daily diet is mainly connected with their valuable mineral ingredients, most of all such elements as Ca, Na, K, Mg, and Mn as well as physiological properties resulting for instance from the caffeine contained in them. In addition to micro and macroelements, beneficial for health, plants of *Camelia sinensis* have the ability to accumulate aluminium, whose contents may reach the level of 1g/kg in dried leaves [4]. Although in general the element does not pose threat for living organisms, in acidic environment it may be highly toxic, which in turn results in numerous health conditions, such as Alzheimer's disease, Parkinson's disease, hence its presence in products raises many controversies.

Although tea has been an object of research for decades, opinions related to nutritional value of and benefits from consuming tea beverages are greatly varied and supported with a consistently growing body of literature providing contradictory evidence.

The purpose of the study was to examine the contents of protein and caffeine as well as mineral elements in infusions, depending on the tea variety. The findings made it possible to assess the nutritional value of infusions from high quality loose-leaf teas in terms of their mineral contents, and the capacity to satisfy the organism's requirements for minerals, additionally taking into account possible hazards resulting from excessive consumption.

## MATERIALS AND METHODS

The research material included 18 high-quality loose-leaf teas of three varieties: black, green and white, produced at Chinese plantations, imported to Poland, and purchased in an online store. Examinations assessed both dried tea leaves and aqueous infusions prepared in the consistent laboratory conditions. Chemical composition such as water, volatiles and ash content of dried tea leaves was determined with the use of TGA701 analyzer manufactured by LECO. For this purpose tea samples were homogenized in Basic Analytical Mill, Type A 11, manufactured by IKA, and prepared for thermogravimetric examination in accordance with the standard [15].

In order to determine water content, weighed samples with a mass of 2 g were placed in crucibles and subjected to continuous drying at the temperature of 103°C until the moment a constant mass was reached at the level below 0.05% at consecutive weight measurements [15]. Ash content was determined taking into account the difference in the weight of the sample after incineration at 550°C in nitrogen atmosphere to the initial mass of the material (approx. 2 gram). The contents of volatile compounds in dry tea leaves were determined by incinerating weighed samples, placed in covered crucibles, at 950°C, for the duration of 20 minutes from the moment the critical temperature was reached [16]. The contents of protein in homogenized dry tea leaves were determined with the use of element analyzer TrueSpec Leco CHNS, and the total protein contents were calculated with the use of an adequate multiplier (6.25). All the analyses were repeated three times.

Tea infusions were prepared in conical flasks. 100 mL of water at the temperature of 100°C was added to the samples with a mass of 1 g. The mixture was covered and brewed for 5 minutes. After this time infusions were trickled via filter paper to measuring flasks and left to cool down. Before analysis the samples were filtered through MCE membrane filters with pore diameter of 0.45 µm and diluted before analysis.

The analyses included examination of the dried tea leaves for their chemical composition (contents of water, protein, volatile substances and ash), and assessment of the tea infusions for the contents of caffeine and selected mineral elements, such as: P, Ca, K, Na, Mg, Zn, Mn, Al.

Caffeine contents in infusions of the investigated teas were determined with the use of high performance liquid chromatography system, Thermo Dionex Ultimate 3000, consisting in a reagent vial coupled with vacuum phase degasser, a module of pumps with eluent mixer at low pressure DGP-3600RS, autosampler WPS-3000, thermostatted column TCC-3X00 and diode array detection DAD-3000 (RS) (ESA Chlemsford. MA. USA). Chromatography separation was performed with the use of chromatography column Cosmosil 5C18-MS-II 4,6ID x 250 mm with a pre-column SecurityGuard with C18 cartridge. Optimum parameters were determined for chromatography analysis. Isocratic flow; composition of the mobile phase: water:methanol 70:30 (v/v), speed of mobile phase flow: 0.6 mL/min; injection volume: 100 µl; temperature inside the thermostatted column: 25ºC, duration of analysis 25 minutes. Operation of the chromatography system and processing of the obtained data were coordinated by software Chromaleon 7.2 (Dionex).

The assay was carried out with reagents of analytical purity grade, methanol manufactured by J.T. Baker, Mallinckrodt Baker B.V. Holland, designed for liquid chromatography, as well as deionized water obtained from HLP 5P deionizer manufactured by Hydrolab Poland.

Anhydrous caffeine (Caffeine Reference Standard) from Sigma Aldrich was dissolved to prepare a model solution with concentration (1g/L) and stored at 4°C. This solution was the basis for preparing working model solutions (2, 4, 6, 8, 10 µg/mL). The basic validation parameters were estimated for the applied analytic method. Specificity of the method was confirmed with model caffeine injections. Linearity of detector response was identified for the programmed concentrations of model solutions at the wavelength of UV1 271 nm and UV2 201 nm.

Mean recovery for tea infusions amounted to 97%. Accuracy of the above analytic method was verified by repeating the injection of the models and each of the samples three times. Stability of the chromatography system was monitored with injections of caffeine solution of known concentration applied every five hours.

Contents of mineral elements in tea infusions were examined with the technique based on inductively coupled plasma atomic emission spectroscopy, with the use of multi-elemental analyzer ICP-OES iCAP Dual 6500 from Thermo Scientific™ (USA). Tea infusions were diluted 1:3 by deionized water directly before the measurement; blind trial was conducted with the use of demineralized water applied for preparing the infusions. The results of measurements were analyzed taking into account model curves drawn for each element, based on three-point scale for model solutions designed by Thermo Scientific™. Correlation coefficient for each curve was in a range exceeding 0.99. Mean recovery for tea infusions amounted to 96-98%. Accuracy of the analytic method was verified by repeating the measurement of the models for each sample three times. Stability of the system was monitored with measurements of a model solution of known concentrations, after 9 measurements of tea samples.

All parts of the experiment were carried out in three independent replicates. The acquired findings were subjected to statistical analyses with the use of Statistica ver. 10.0. Relationships of specific constituents in the examined material were estimated taking into account *Pearson* correlation coefficient. The results were also analysed statistically with the one factor 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 the large differences between the selected kinds of tea. 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. Yet, it is possible to identify, within each group, the products with the most beneficial contents of minerals and nutrients. Tables 1, 2, and 3 present mean findings related to the chemical composition in the selected brands of Chinese white, green and black teas, while Tables 4, 5 and 6 show the findings related to mineral elements and caffeine identified in infusions of selected brands of Chinese teas. Table 7 presents statistically significant differences between means of nutrition components, minerals and caffeine in different types of Chinese tea.

Table 1. Mean values and standard deviations in the analysis of chemical composition in Chinese black teas.

| Name of tea | Content (%) | | | |
|---|---|---|---|---|
| | Protein | Water | Volatiles | Ash |
| Lapsang Souchong | **20.28±0.52** | **7.07±0.06** | **2.89±0.43** | **5.81±0.07** |
| Bi Hong Cha | **22.72±1.00** | **6.83±0.15** | **2.75±0.30** | 5.37±0.14 |
| Yunnan Gold | 16.79±2.27 | 6.02±0.18 | **2.90±0.58** | **6.10±0.04** |
| Yunnan | 19.74±1.33 | 6.80±0.04 | 2.67±0.24 | 5.63±0.09 |
| Russian Caravan | 18.07±0.23 | **7.23±0.16** | 2.69±0.20 | 5.66±0.04 |
| Keemun Mao Feng | **23.68**±0.66 | 5.02±0.06 | 2.68±0.53 | 5.43±0.07 |

Table 2. Mean values and standard deviations in the analysis of chemical composition in Chinese green teas

| Name of tea | Content (%) | | | |
|---|---|---|---|---|
| | Protein | Water | Volatiles | Ash |
| Bi Hong Green Cha | 28.66±0.77 | **5.63±0.28** | **2.65±0.53** | 5.06±0.16 |
| Fog Green Tea | **41.32±1.12** | 3.23±0.08 | 2.41±1.09 | **5.25±0.08** |
| AnJi Bai Cha | **41.36±0.78** | **5.98±0.12** | 2.56±0.62 | 5.07±0.07 |
| Lu An Gua Pian | 36.70±0.33 | 3.94±0.04 | **2.59±0.31** | **6.01±0.20** |
| Pi Lo Chun | **40.02±1.30** | 5.81±0.11 | 2.43±0.35 | 5.16±0.11 |
| Yunnan Green | 37.03±0.55 | **6.60±0.06** | **2.67±0.07** | **6.09±0.11** |

Table 3. Mean values and standard deviations in the analysis of chemical composition in Chinese white teas

| Name of tea | Content (%) | | | |
|---|---|---|---|---|
| | Protein | Water | Volatiles | Ash |
| Yin Zhen Chu | **35.71±0.25** | 6.03±0.12 | **3.01±0.08** | 4.47±0.09 |
| Pai Mu Tan | 29.43±1.61 | **6.38±0.08** | **2.84±0.10** | **4.94±0.10** |
| Hao Yin Zhen | **34.65±0.24** | **7.00±0.28** | 2.47±0.21 | 4.78±0.04 |
| Mao Feng Le | **30.22±0.33** | 5.24±0.09 | **2.70±0.04** | **5.14±0.17** |
| China White Pearl | 23.62±0.74 | 5.75±0.08 | 2.65±0.05 | **5.57±0.11** |
| Paklum I | 29.55±0.48 | **8.89±0.04** | 2.80±0.31 | 4.01±0.06 |

Table 4. Mean values and standard deviations in the analysis of selected mineral elements and caffeine contained in infusions of Chinese black teas

| Name of tea | Content (mg/100 mL) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | P | Ca | K | Na | Mg | Zn | Mn | Al | Caffeine |
| Lapsang Souchong | 1.07±0.01 | 0.14±0.00 | 5.69±0.08 | 0.02±0.00 | 0.38±0.06 | 0.01±0.00 | 0.08±0.00 | 0.12±0.01 | 31.50±0.23 |
| Bi Hong Cha | 1.05±0.02 | 0.06±0.00 | 6.97±0.25 | 0.00±0.00 | **0.48**±0.03 | 0.01±0.00 | **0.14**±0.00 | 0.06±0.00 | **35.72±0.57** |
| Yunnan Gold | 0.90±0.02 | 0.11±0.00 | 6.75±0.50 | **0.03**±0.00 | 0.44±0.03 | 0.01±0.00 | 0.08±0.00 | 0.12±0.01 | 32.32±0.42 |
| Yunnan | 1.07±0.11 | **0.21**±0.00 | **7.82**±0.24 | **0.04**±0.00 | **0.53**±0.01 | 0.01±0.00 | 0.09±0.00 | **0.18**±0.01 | 33.09±1.19 |
| Russian Caravan | 1.01±0.02 | 0.11±0.00 | **7.72**±0.22 | 0.02±0.00 | 0.36±0.02 | 0.01±0.00 | **0.11**±0.00 | **0.15**±0.01 | **33.92±0.70** |
| Keemun Mao Feng | **1.95**±0.02 | **0.18**±0.00 | **10.73**±0.31 | 0.02±0.00 | **0.49**±0.02 | **0.02**±0.00 | **0.13**±0.00 | 0.04±0.00 | **43.42±0.97** |

According to experts in commodities science, white tea brands are the most exclusive and refined group of products. This type of tea is produced from shrubs of *Camellia sinensis* and more specifically, from young buds of still undeveloped leaves, covered with silvery hairs which infuse the pale yellow beverage with the characteristic silvery tinge and gentle aroma. Analysis of the present findings allows a conclusion that the contents of selected basic components are similar to those identified in green teas. The contents of protein, as a proportion of dry matter, ranged from 23 to 35% in white teas, and from 28 to 41% in green teas. Despite the greater content of water (5.2-9%) in comparison to the products in the other groups, white teas were found with high content of volatile substances, and the lowest content of ash, which is also confirmed by the quantitative contents of selected elements. The product with the highest content of mineral elements among the white teas was *China White Pearl,* ranked by the distributor of tea among the brands with particularly refined flavour. The elements dominating in infusions based on this tea brand included P, Mg, and Ca, yet the relevant values were not as high as in the green teas, among which *Yunnan Green* stood out for its mineral contents. Green teas were characterized by the most valuable composition of minerals, in quantitative terms, yet they were also found with equally high content of aluminium, which adversely affects health. On the other hand black teas, with the content of protein approximately half the size in comparison with green and white teas, were identified with higher levels of caffeine, total ash and volatile substances which would confirm the stimulating effect and the strong aroma of this type of tea. In the group of black teas the most valuable composition of minerals was found in *Keemun Mao Feng*, which stood out for the high contents of P, Ca, K, Mg, Zn and Mn and the low contents of Al; yet with regard to the contents of such elements as Ca, Na and Zn significantly better values were found in infusions of *Yunnan Green* tea. Generally, the white teas did not stand out for their health enhancing parameters, while on average the mineral composition of these infusions and their low caffeine contents, in comparison with the black teas, seem to reflect the soothing and calming effect of this variety of tea. The green teas have significantly higher nutritional value; in addition to the lower content of caffeine than in the black teas, they contain highly beneficial minerals which may cover significant part of the daily intake levels for selected microelements. Yet, it is necessary to remember about the contents of aluminium which in green teas is higher than in the other groups of products.

Green teas, highly popular among consumers in China and Japan, are significantly less appreciated in European countries. Leaves of green tea are not subjected to fermentation; after initial vaporization of water wilted leaves are subjected to a process of delicate rolling, and then additional drying, sorting and packing. As a result green tea has similar chemical composition to fresh tea leaves and it retains more beneficial elements that black tea. The infusions have more delicate, slightly pungent taste and fresh spicy or floral aroma [19].

Table 5. Mean values and standard deviations in the analysis of selected mineral elements and caffeine contained in infusions of Chinese green teas

| Name of tea | Content (mg/ 100 mL) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | P | Ca | K | Na | Mg | Zn | Mn | Al | Caffeine |
| Bi Hong Green Cha | 0.85±0.03 | 0.36±0.00 | **9.51±0.20** | 0.12±0.00 | **0.78**±0.00 | 0.02±0.00 | **0.26**±0.01 | 0.08±0.00 | **34.55±0.85** |
| Fog Green Tea | **1.23**±0.05 | 0.34±0.00 | **8.97**±0.06 | 0.45±0.01 | **0.68**±0.00 | 0.03±0.00 | **0.16**±0.00 | 0.03±0.00 | **30.88±0.51** |
| An Ji Bai Cha | **1.32**±0.01 | 0.49±0.00 | 8.34±0.31 | 0.86±0.02 | 0.44±0.01 | 0.03±0.00 | 0.07±0.00 | 0.04±0.00 | 19.46±0.45 |
| Lu An Gua Pian | 0.96±0.03 | **0.96**±0.03 | **9.47**±0.47 | **9.47**±0.47 | 0.58±0.01 | **0.84**±0.01 | 0.03±0.00 | **0.28**±0.00 | **28.55±0.49** |
| Pi Lo Chun | 1.22±0.01 | **1.22**±0.01 | 8.47±0.47 | **8.47**±0.47 | **0.66**±0.02 | **0.76**±0.00 | 0.03±0.00 | **0.28**±0.01 | 24.14±0.41 |
| Yunnan Green | **1.24**±0.01 | **1.24**±0.01 | **10.52**±0.44 | **10.52**±0.44 | 0.45±0.01 | **0.89**±0.02 | 0.04±0.00 | **0.18**±0.00 | 18.83±0.44 |

Table 6. Mean values and standard deviations in the analysis of selected mineral elements and caffeine contained in infusions of Chinese white teas

| Name of tea | Contents (mg/ 100 mL) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | P | Ca | K | Na | Mg | Zn | Mn | Al | Caffeine |
| Yin Zhen Chu | 0.94±0.01 | **0.32**±0.00 | 6.31±0.28 | **0.08**±0.00 | 0.37±0.01 | **0.03**±0.00 | 0.11±0.01 | 0.02±0.00 | **34.07±0.71** |
| Pai Mu Tan | **1.33±0.00** | 0.20±0.02 | **7.20**±0.01 | **0.06**±0.00 | 0.41±0.01 | 0.02±0.00 | 0.08±0.00 | **0.08**±0.01 | **38.33±1.60** |
| Hao Yin Zhen | 0.88±0.01 | 0.18±0.00 | 4.73±0.24 | 0.05±0.00 | 0.27±0.01 | 0.02±0.00 | 0.06±0.00 | 0.01±0.00 | 30.06±0.41 |
| Mao Feng Le | 0.96±0.01 | **0.31**±0.01 | **8.73**±0.19 | 0.05±0.00 | **0.59**±0.01 | 0.02±0.00 | **0.20**±0.00 | 0.02±0.00 | 29.04±1.15 |
| China White Pearl | **1.04**±0.00 | **0.27**±0.01 | **9.01**±0.23 | 0.04±0.00 | **0.74**±0.05 | 0.01±0.00 | **0.14**±0.00 | **0.04**±0.00 | 28.86±0.35 |
| Paklum I | 0.38±0.00 | 0.17±0.00 | 2.62±0.42 | 0.03±0.00 | 0.08±0.01 | 0.01±0.00 | 0.02±0.00 | 0.01±0.00 | 13.11±0.46 |

Dried leaves of green teas, unfermented, but only subjected to steam drying, in the final standardization of the product contained the lowest amount of water in comparison to the other kinds of tea. The contents of volatile substances and ash did not differ significantly from the values of these parameters in black and white teas. Interestingly, the contents of protein were twice the value found in some of the black teas. Green tea from Yunnan plantation, like in the case of the black teas, stood out for the contents of beneficial minerals such as magnesium, potassium, phosphorus and zinc, with a significant amount of the less beneficial element, i.e. Al. Similar findings were reported by *Ferrara* et al. [3], who examined the contents of mineral elements and phenolic compounds in selected tea varieties. Caffeine contents were greatly varied in the group of green teas and similar to the values identified in the white teas.

Despite the varied parameters of the basic composition in the examined types of tea, in terms of the science of commodities all the products comply with the standard whereby the contents of water should not exceed 8% [16] and the range for the contents of ash lower than 4% and not higher than 8% [18].

Table 7. The content of nutrition components, minerals and caffeine in different types of Chinese tea

| | Component | Type of tea | | |
|---|---|---|---|---|
| | | Black | Green | White |
| % | Protein | 20.215$^{DF}$ | **37.015**$^{AC}$ | 30.531$^{BE}$ |
| | Water | 6.496$^{C}$ | 5.072$^{BD}$ | **6.549**$^{A}$ |
| | Volatiles | **2.769**$^{A}$ | 2.578$^{BD}$ | 2.754$^{C}$ |
| | Ash | **5.666**$^{A}$ | 5.497$^{C}$ | 4.817$^{BD}$ |
| mg/100 mL | P | 1.175$^{a}$ | 1.119 | 0.905$^{b}$ |
| | Ca | 0.137$^{DF}$ | **0.398**$^{AC}$ | 0.239$^{BE}$ |
| | K | 7.613$^{B}$ | **9.363**$^{AC}$ | 6.433$^{D}$ |
| | Na | 0.020$^{D}$ | **0.492**$^{AC}$ | 0.052$^{B}$ |
| | Mg | 0.446$^{B}$ | **0.723**$^{AC}$ | 0.411$^{D}$ |
| | Zn | 0.011$^{DF}$ | **0.033**$^{AC}$ | 0.021$^{BE}$ |
| | Mn | 0.106$^{B}$ | **0.188**$^{AC}$ | 0.102$^{D}$ |
| | Al | **0.110**$^{AC}$ | 0,069$^{BE}$ | 0.029$^{DF}$ |
| | Caffeine | **34.997**$^{AC}$ | 26.455$^{D}$ | 28.584$^{B}$ |

Statistically significant differences between means (A-F for $p \leq 0.01$; a-b for $p \leq 0.05$), marked by different letter in the rows

The contents of specific mineral elements in tea infusions have been an object of research for many years, mainly because of the frequent consumption of tea, its popularity and lack of age or physiology related limitations for its consumption. There has even been a study focusing on the relationship between tea consumption and degree of satisfying organism's daily requirements for selected minerals *Gallaher* et al. [5] questioned the hypothesis claiming that tea infusions are a good source of micro and macroelements in daily diet, and they demonstrated low extraction rates for selected elements (at the level of 24% Mg, 35% Zn, 43% P, 71% K) and poor nutritional value of aqueous infusions produced from various teas. According to these authors consumption of as many as 10 cups of tea does not provide the bottom daily value e.g. of sodium. Other authors [18], taking into account analytical characteristics of green teas, noticed the wealth of such minerals as Ca, K, Na, Mn, and Mg, and provided evidence, contrary to that presented by the previously mentioned researchers [5], showing that because of the quantities of the selected elements contained in them, the infusions may be an important source of minerals, satisfying the daily requirements. Accordingly, *Reto* et al. [18] demonstrated that the contents of manganese in a cup of tea (approx. 225 mL), taking into account 40% bioavailability of this element, may satisfy 10% of the daily dietary intake. Furthermore, caffeine contents in the examined green teas were found in the range of 23-33mg/100 mL, which is consistent with the present findings. Higher contents of mineral elements in green than in black teas were also reported by *Ferrara* et al. [3]. Moreover, based on chromatographic examinations the latter authors also confirmed higher contents of polyphenolic compounds in green teas, compared to black teas, consistently with the findings reported by *Hilal* and *Engelhardt* [9] who compared the contents of biologically active substances in three kinds of tea: white, green and black. Different findings in comparison to those obtained in the present study are related to caffeine contents in three kinds of tea examined by *Hilal* and *Engelhardt* [9], with the use of HPLC method. According to those authors white teas contain the largest quantities of this alkaloid, while comparable contents were identified in black and green teas. *Drywien* et al. [2] suggested that black tea provided a better dietary source of polyphenols than green tea because it was drunk more by thrir studied subjects and also it can be the same with minerals. Based on analysis of minerals and in variety dried tea *Gajewska* et al. [6] found that black tea contains more minerals than green tea which is also consistent with the present findings by comparing the total ash content in the analyzed teas (Table 3.)

Caffeine, which belongs to the group of methylxanthines, occurs in numerous plants. Due to its physiologic effects it is classified among natural stimulants, and the presence of caffeine in numerous food products, such as coffee, tea, cocoa and energy drinks suggests it is necessary to limit its consumption. High consumption of caffeine or products containing it, may affect individuals who are particularly sensitive to the stimulating action of this alkaloid and induce headaches, migraine, tremor of the extremities, insomnia, or contribute to dehydration due to its diuretic properties

[21]. Caffeine is also a component of many painkillers and pharmaceutical stimulants manufactured worldwide, and due to this its consumption is regulated by the Federal Food and Drug Administration which imposes a requirement to provide relevant information on product labels. Unfortunately the labelling obligation relates to products containing caffeine of exogenous origin, and the regulation does not apply to products with naturally occurring caffeine, such as tea [8].

The contents of caffeine in the white teas used in the present study were in the wide range from 12 mg to 38 mg/100 mL. According to many authors, the contents of methylxanthines, including caffeine, in tea infusions constitute a stable physicochemical parameter and no unanimous evidence has been reported regarding the influence of the processing technologies on the contents of these substances in dried tea leaves or in tea infusions. The most important parameters in this case include the conditions of extraction, i.e. preparing the infusion, temperature of water, and time of brewing, as well as stirring and shaking the samples during extraction. Paklum I brand white tea, just like in the case of the other physicochemical parameters, stood out for the lowest caffeine contents, three times lower in comparison to the remaining products of this group; on the other hand the highest content of caffeine, in the range of 31-43 mg/100 mL, was identified in infusions of black tea, in particular Keemun Mao Feng, which additionally had the highest contents of zinc, phosphorus and potassium. According to the distributor of the examined Chinese teas, this product ranks among the most important Chinese teas, and its refined quality is a result of delicate manually performed processing of the leaves after harvest [22]. The fact that black teas are popular among consumers is linked with their stimulating properties, resulting from the high contents of methylxanthines (caffeine), confirmed in the infusions of the selected products of this group. Caffeine contents in the black teas on average were 20% higher than in the white and green teas.

According to *Jarosz* et al., [11] caffeine contents in black and green teas are comparable. On the other hand *Iso* et al. [10] reported that caffeine contents in infusions based on black teas were twice as high as in green tea infusions, which is consistent with the present findings.

As a rule it is difficult to choose products which are new to the market; for instance in the case of tea beverages one may be surprised with their taste and flavour as well as their physiological effect. Table 8 presents correlation coefficients for the examined groups of products to enable comparison of links between specific constituents of tea beverages.

Table 8. Coefficients of correlation between the contents of protein, caffeine and mineral elements in infusions of black, green and white teas

| Type of tea | Parameter | Mineral elements | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | P | Ca | K | Na | Mg | Zn | Mn | Al |
| Black | protein | 0.73 | 0.1 | 0.52 | -0.5 | -0.46 | 0.01 | 0.74 | -0.72 |
| | caffeine | 0.94 | 0.22 | 0.92 | -0.32 | 0.39 | 0.51 | 0.74 | -0.74 |
| Green | protein | 0.87 | 0.15 | -0.49 | 0.09 | -0.42 | 0.07 | -0.62 | -0.04 |
| | caffeine | -0.77 | -0.56 | 0 | -0.46 | 0.91 | -0.41 | 0.76 | -0.17 |
| White | protein | -0.12 | 0.04 | -0.44 | 0.62 | -0.87 | 0.45 | -0.23 | -0.4 |
| | caffeine | 0.96 | 0.36 | 0.64 | 0.77 | 0.51 | 0.78 | 0.43 | 0.62 |

Assessment of the material for co-occurrence of selected components of the highest dietary significance focused on comparing the relations between protein in dried tea leaves and caffeine as well as mineral composition of the tea infusions. The aim of this comparison was to evidence if there is some relations between the minerals which are extracted to tea infusion when they has for example high concentration of protein in dried leaves of tea or caffeine in tea infusions. There was a strong positive correlation between contents of caffeine in infusions based on black teas and selected mineral elements such as phosphorus, potassium, zinc and manganese. Similar correlation was also found in the case of protein in the black teas. On the other hand an increase in the contents of protein and caffeine correlated negatively with the contents of aluminium, which may suggest greater nutritional value and safety of consumption in the case of these products. In the green teas the findings showed negative correlation between the contents of protein and the contents of potassium and manganese, as well as between the contents of caffeine and the contents of phosphorus, calcium and sodium, i.e. elements of high dietary importance. Similarly, at higher contents of caffeine, green teas were found with lower contents of calcium, phosphorus and sodium as well as higher contents of magnesium and manganese. The findings for the white teas showed strong positive correlation between all the examined mineral elements, including aluminium. On the other hand the contents of protein correlated positively with sodium and zinc and highly negatively with potassium and magnesium contained in these products. Positive correlation for the contents of aluminium adversely affects dietary assessment of high-quality white teas, the only ones to be identified with a positive correlation in the case of this element. Data reported in literature with regard to specific mineral elements contained in teas suggest that aluminium raises the greatest concerns because it was shown many times that its migration from tea leaves to the infusions occurs easily and effectively in practically any conditions in which tea beverages are prepared [13]. Moreover, other authors have reported that mineral composition of dried tea leaves, in addition to soils and climate, depends on the age of the leaves and the order in which they develop on the shrub [4]. Furthermore, it was shown by *Matsuura* et al. [13] that effectiveness of extraction during the process of brewing is significantly lower in the case of some elements, e.g. Fe in comparison to Cu, Zn and Mn, so despite the relatively high content of such elements in fresh or dried tea leaves, beverages made from them do not necessarily constitute a good source of such elements. Analyses of mineral composition from nutritional point of view should mainly focus on elements which are required by the human body in small amounts only, yet they also rarely occur in other products, like e.g. Mn. Analysis of correlations between the selected mineral elements, caffeine and protein in the three kinds of tea showed relationships in particular in the case of green tea which should be recognized as a leading product in terms of its mineral composition. The highest contents were found in the case of zinc, manganese, magnesium, potassium and calcium. The values of these parameters in black teas, for zinc and calcium were lower by approx. 66-70%, in the case of manganese and magnesium were nearly half the value, and for potassium were lower by 15%.

To sum up the analysis of the mean values of parameters characterizing three types of tea infusions it is possible to conclude that a great majority of them, in particular green tea infusions, enhance the organism's mineral balance. Green teas are a valuable source of protein, and white teas present a wide range of volatile substances, which may reflect the rich aromas. Black teas definitely dominate in terms of caffeine contents, yet this parameter is still an object of research and no explicit evidence for this relationship has been demonstrated.

## CONCLUSIONS

1. High-quality Chinese green teas were found with the most valuable composition of minerals, i.e. the highest contents of Zn, Mn, Mg, K, Ca and Al and, in comparison to the other examined products, the highest contents of protein, on average at the level of 37.03% in the dry mater.
2. Chinese black teas had the highest contents of total ash and caffeine, approx. 35.1mg/100 mL of the infusion, and the lowest content of protein, approx. 20.2%.
3. White teas from Chinese plantations were characterized with high content of volatile substances, similar to the black teas, and the highest content of water, the lowest content of total ash, on average at the level of 4.82% and caffeine approx. 29.6mg/100 mL of the infusion.

**Conflict of interest**

*The authors declare no conflict of interest.*

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