Magnetic Field Extraction Techniques in Preparing High-Quality Tea Infusions

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Abstract: Tea is one of the most popular drinks in the world, commonly consumed by consumers from all age groups mainly due to its refreshing taste, attractive aroma, and potentially beneficial impact on health. The composition of a tea drink depends on numerous factors, such as time and brewing temperature, degree of crumbling of tea leaves, and degree of mixing. Diffusion of the polyphenolic compounds, minerals, caffeine or theanine typical of tea infusions have been the subject of studies conducted by numerous authors. Promoting the extraction of amino acids from tea leaves when preparing infusions through the induction of a magnetic field constitutes not only another step towards the optimisation of the extraction process, but is also one of the methods to improve the nutritional value of tea infusions. The purpose of this work was to verify a hypothesis concerning the improvement of the extraction of amino acids from dried tea during the preparation of infusions by applying a permanent or variable magnetic field induced under laboratory conditions. A variable magnetic field applied as a factor assisting extraction resulted in an increased concentration in the total number of amino acids in green and black tea infusions. A statistically significant improvement in the level of free amino acids was observed after application of extraction assisted by a variable magnetic field with induction at 100 mT and a frequency of 50 Hz. Extraction using a variable magnetic field for tea infusions may constitute a good solution to assist traditional water extraction methods for research purposes.

Keywords: teas; amino acids; extraction; magnetic field

1. Introduction

Tea is one of the most popular drinks in the world, commonly consumed by consumers from all age groups mainly due to its refreshing taste, attractive aroma, and potentially beneficial impact on health [1]. Aromatic tea infusions owe their origin to two botanical varieties of tea bushes Camellia sinensis var. assamica, the leaves of which, collected at various stages of their development, constitute the basic raw material for the production of dried tea. Processing of tea leaves depends on the type of tea and the quality of the final product [2]. In the case of high-quality tea, most technological processes are carried out manually, and young shoots, undeveloped buds, delicate stems, and the first, small leaves of tea bushes are selected during collection [3]. Black tea is consumed throughout the world, while green tea is consumed mainly in Asia and North Africa; however, green tea as well as teas with flower petals, herbs, roots, dried fruit or fruit aromas have been purchased with an increasing frequency due to their taste and health benefits [4]. Black tea is obtained through the enzymatic fermentation of catechin polyphenols contained in leaves, and the multi-stage production process is conducted under strictly defined conditions. Oxidation of catechins leads to the occurrence of the main pigments theaflavin and thearubigin, which give tea infusions their typical orange and
amber colour [5]. A variety of tea available on the market is determined not only by the taste, aroma, colour, type of additives or country of origin, but as can be concluded from Table 1, most of all by the chemical composition and content of nutrients and bioactive ingredients. Freshly brewed water solutions of dried leaves of *Camellia sinensis* constitute a mixture of approx. 300 different compounds responsible for the typical features and taste attributes of tea [6,7]. The composition of a tea drink depends on numerous factors, such as: time and brewing temperature, degree of crumbling of the tea leaves, and degree of mixing.

**Table 1.** Characteristics of the tea selected for analysis. SD: standard deviation.

| Type of Tea | Name         | Origin          | Water  | Volatiles | Ash     | Protein   |
|------------|--------------|-----------------|--------|-----------|---------|-----------|
| green      | Sencha       | Japan           | 6.13 ± 0.10 | 3.01 ± 0.08 | 4.47 ± 0.09 | 25.71 ± 0.25 |
|            | Gyokuro      | Japan           | 6.04 ± 0.06 | 2.84 ± 0.10 | 4.94 ± 0.10 | 29.63 ± 0.81 |
|            | Banca        |                 | 7.10 ± 0.18 | 2.7 ± 0.21 | 4.78 ± 0.04 | 24.65 ± 0.14 |
| black      | English Breakfast | Sri Lanka, India | 7.04 ± 0.19 | 2.70 ± 0.04 | 5.14 ± 0.17 | 20.25 ± 0.35 |
|            | Darjeeling   | India           | 6.15 ± 0.12 | 2.65 ± 0.05 | 5.57 ± 0.11 | 23.62 ± 0.74 |
|            | Yunnan       | China           | 6.89 ± 0.08 | 2.80 ± 0.31 | 4.01 ± 0.06 | 21.59 ± 0.48 |

In traditional methods of preparing infusions from teas, it is recommended to use a higher water temperature of about 95 °C for fermented teas (black and red) and lower water temperature (about 75 °C) for unfermented teas (green and white). In addition, the temperature of the water and the brewing time affect the selective extraction of the individual components from the tea leaves, and thus give specific properties for the infusions, e.g., stimulants, when caffeine contained in the tea leaves diffuse into the water. Iso et al. [8] reported that caffeine contents in infusions based on black teas were twice as high as in green tea infusions. According to their research, these substances are the most easily extracted into infusions in the first minutes of brewing tea and their content decreases with increasing the brewing time due to the condensation of catechins. Hilal and Engelhardt [3] compared the contents of biologically active substances in three kinds of tea: white, green and black confirmed higher contents of catechins in green teas compared to black teas, therefore they have a relaxing influence on the body. To obtain such properties of infusions, lower water temperatures and extended brewing times should be used so that the infusion will penetrate antioxidants, minerals, and also amino acids that have a calming effect on the nervous system [9].

Diffusion of polyphenolic compounds, minerals, caffeine or theanine typical of tea infusions have been the subject of studies conducted by numerous authors [10–12]. According to Koch et al. [13,14] catechins are the major constituents responsible for properties and quality of green as well black teas. Average black or green teas also contains approx. 6% of free amino acids in the dry matter content, which according to Alcazar et al. [15] are the ingredients responsible for the taste of tea and determine its quality. Both protein amino acids, especially essential ones, as well as non-protein, such as theanine or GABA (gamma-aminobutyric) acid, present in tea fulfil a very important role as precursors of bioactive and health-promoting substances and components of polyphenol or glutathione biosynthesis [16]. Free amino acids also have a great nutritional value as easily available substrates for numerous biochemical and metabolic changes in the human body, therefore their presence in food is exceptionally valuable and desired [17,18].

To significantly improve the effectiveness of the diffusion of substances for solutions, the currently traditional water extraction using high temperatures and a long extraction time can be preceded by techniques to assist extraction, such as supercritical CO₂ extraction [19,20]. Such methods have been used during experiments concerning the decaffeination of coffee and tea and the improved efficiency of hop oil extraction [21]. Another way to assist water extraction of ingredients is microwave radiation [22,23] and the most popular method uses ultrasounds [24,25]. The extraction methods improved by different factors are widely described by Zagula et al. [26]. Assisting the extraction of amino acids from tea leaves during the preparation of infusions through the induction of a magnetic
field, suggested by the authors of this work, constitutes not only another step towards the optimisation of the extraction process, but it is also one of the means to improve the nutritional value of tea infusions. The aim of the study was to analyse the effect of constant and variable magnetic field induced in laboratory conditions on the extraction of amino acids from tea dried during infusion. The purpose of this work was to verify the hypothesis that a permanent or variable magnetic field may improve the concentration of amino acids in tea infusions. The proposed method of extraction with the impacts of magnetic field may be used at the industrial scale or for laboratory purposes, because for the general population, preparing tea infusion in the home space using this method is not able to replace traditional tea brewing using hot water.

2. Materials and Methods

2.1. Tea Samples

Six high-quality types of black and green leaf tea (Camellia sinensis var. sinensis and Camellia sinensis var. assamica) purchased from the eherbata.pl online store constituted the research material. Table 1 presents the characteristics of the dried tea selected for analysis. The chemical composition, such as water, volatiles, and ash content of dried tea leaves, was determined with the use of a TGA701 analyser manufactured by LECO (St. Joseph, MI, USA). For this purpose, tea samples were homogenised in a Basic Analytical Mill, Type A 11, manufactured by IKA (Guangzhou, China), and prepared for thermogravimetric examination in accordance with the appropriate standard [27]. The protein contents in homogenised dry tea leaves were determined with the use of a TrueSpec Leco CHNS element analyser (LECO, St. Joseph, MI, USA), and the total protein contents were calculated with the use of an adequate protein multiplier (6.25). All the analyses were repeated three times.

2.2. Analytical Procedures

Tea infusions were prepared by pouring 100 mL of demineralised water over 2 g of dried tea. Deionised water was obtained using a HLP 5P deioniser manufactured by Hydrolab Poland (Straszyn, Poland). The brewing process was conducted in closed flat bottom beakers with a diameter of 8 cm, without stirring for 5 min, in three variants: (1) control conditions (C), (2) extraction assisted by a permanent magnetic field (PMF) with induction at 100 mT, (3) extraction assisted by a variable magnetic field (VMF) with a frequency of 50 Hz and induction at 100 mT. Each extraction was carried out in three independent repetitions. A permanent magnetic field was induced between a pair of neodymium magnets 10 cm apart from one another. The stability of the magnetic field distribution is presented in Figure 1. In order to induce a variable magnetic field, an inductive coil with current supplied from an AC autotransformer (University of Rzeszow, Rzeszow, Poland) was used. Stabilisation of the conditions of operation of the coil is presented on Figure 2 [26].

Immediately after completing the extraction process, a sample of the infusion was collected from each sample and analysed using the Automatic Amino Acid Analyser type S433 manufactured by Sykam (Eresing, Germany).

Green and black tea infusions prepared under specified conditions were filtered before analysis through a syringe filter with pores 0.22 µm in diameter and diluted four times with a diluting buffer with pH = 2.2. The S433 Automatic Amino Acid Analyser set consisted of a specialised HPLC device composed of a cooling chamber for reagents with a degasser type S7130, an autosampler type S5200 with cooling, a reaction chamber type S4300, a set of columns for the analysis of physiological amino acids consisting of an amine precolumn (100 mm × 4.6 mm), and a cation exchange separation column (150 mm × 4.6 mm). Buffers, such as lithium citrate with pH = 2.9, lithium citrate with pH = 4.2, lithium borate with pH = 8.0, and a solution for column regeneration after completion of amino acid separation were used for separation. All reagents placed in the cooled chamber were additionally stored in an inert gas atmosphere (argon). Ninhydrin (Sykam, Eresing, Germany) was used for the colour reaction of amino acids. Buffers, ninhydrin, and a mixture of standards for the identification
of amino acids were manufactured by Sykam and they were standardised for the analysis of amino acids in the physiological natural physiological range. Injection volume for the sample and mixture of standards was 10 µL and exchangeable sample loop was 100 µL. Separation of amino acids was conducted at a gradient at 80 °C and postcolumn derivatization in the reaction chamber with ninhydrin at 130 °C. The time of analysis was 110 min. The basic validation parameters were estimated for the applied analytic method. Specificity of the method was confirmed with model solution of 35 amino acids injections with basic concentration 0.25 µmol ml⁻¹. Linearity of detector response was identified for the programmed concentrations of model solutions at the wavelength of 440 and 570 nm. Mean recovery for tea infusions amounted up to 90% for black teas and 96% for green teas. 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 analytical system was monitored with injections of standard solution of known concentration applied every 10 samples.

Figure 1. Distribution of the permanent magnetic field with induction B = 100 mT, within the sample extract.

Figure 2. Distribution of the variable magnetic field with induction B = 100 mT and frequency f = 50 Hz, within the sample extract.

All parts of the experiment were carried out in three independent replicates. The findings obtained were subjected to statistical analyses with the use of Statistica ver. 10.0 (Statsoft, Krakow, Poland). The results were analysed statistically with two factors analysis of variance (ANOVA) and differences between means were assessed using the Duncan test.
3. Results and Discussion

3.1. Profiles of Amino Acids in Different Tea

The analysis of substances with a nutritional value including amino acids present in infusions of the selected teas allowed us to determine their quality and nutritional attributes. The average values of the analysis of free amino acids in infusions of high-quality green (Table 2) and black (Table 3) tea prepared using extraction assisted by a permanent or variable magnetic field are presented below.

Table 2. Impact of the type of tea and manner of brewing on the content of amino acids in infusions of high-quality green tea.

| Component        | Name of Tea | Brewing Conditions |
|------------------|-------------|--------------------|
|                  | Sencha      | Gyokuro            | Bancha | C  | PMF | VMF |
| mg L⁻¹            |             |                    |        |    |     |     |
| Theanine         | 138.39 B,E  | 144.37 A,C         | 132.11 D,F | 137.63 D | 140.30 B | 146.70 A,C |
| Aspartic Acid    | 16.96 B,E   | 20.47 A,C          | 13.48 D,F | 14.64 B | 15.68 D | 20.44 A,C |
| Threonine *      | 31.31 D     | 39.60 A,C          | 31.61 B | 30.02 | 30.18 | 31.21 |
| Glutamic Acid    | 233.47 B,E  | 223.04 D,F         | 251.66 A,C | 229.41 | 230.58 | 231.28 |
| Proline          | n/a         | n/a                | n/a    | n/a | n/a | n/a |
| Alanine          | 18.80 B,E   | 25.47 A,C          | 17.08 D,F | 18.57 D | 18.99 B | 23.52 A,C |
| Methionine *     | n/a         | n/a                | n/a    | n/a | n/a | n/a |
| Isoleucine *     | 17.73 B,D   | 20.78 A            | 19.06 C | 16.73 D | 17.27 B | 23.46 A,C |
| Leucine *        | 17.02 D,F   | 28.92 A,C          | 23.40 D,F | 20.71 B | 20.38 B | 26.48 A,C |
| Tyrosine         | 15.76 A,C   | 10.03 B            | 9.83 D  | 11.96 | 11.32 | 12.02 |
| Phenylalanine *  | 22.01 B,E   | 27.47 A,C          | 19.56 D,F | 21.01 B | 20.88 B | 23.04 A,C |
| GABA             | 34.54 B,E   | 37.05 A,C          | 26.63 D,F | 28.35 D | 29.47 B | 36.41 A,C |
| Lysine           | 8.02 C      | 8.16 A             | 6.86 B,D | 7.53 | 7.42 | 8.06 |
| Histidine        | 18.65 D,F   | 25.21 A,C          | 20.82 B,E | 18.73 | 18.45 | 19.02 |
| Tryptophan *     | 10.64 D,F   | 16.18 A,C          | 11.37 B,E | 9.87 | 10.12 | 11.06 |

*—essential amino acids; C—control samples; PMF—permanent magnetic field, VMF—variable magnetic field. Statistically significant differences between means (A-F for p ≤ 0.01), marked by different letters in the rows.

Table 3. Impact of the type of tea and manner of brewing on the content of amino acids in infusions of high-quality black tea.

| Component        | Name of Tea | Brewing Conditions |
|------------------|-------------|--------------------|
|                  | English Breakfast | Darjeeling | Yunnan | C | PMF | VMF |
| mg L⁻¹            |             |                    |        |    |     |     |
| Theanine         | 86.21 D     | 108.65 A,C         | 87.44 D | 91.87 | 91.53 | 91.99 |
| Aspartic Acid    | 11.50 D     | 13.69 A,C          | 12.31 B,E | 11.49 D | 11.65 B | 13.36 A,C |
| Threonine *      | 19.80 A,C   | 14.91 B,E          | 12.03 D,F | 14.61 B | 14.48 D | 16.83 A,C |
| Glutamic Acid    | 119.81 D    | 148.92 A,C         | 120.32 B | 129.24 D | 130.14 B | 131.68 A,C |
| Proline          | 8.11 D      | 9.98 B             | 11.62 A,C | 8.98 | 8.91 | 9.05 |
| Alanine          | 19.45 D,F   | 26.92 A,C          | 20.49 B,E | 20.47 | 20.51 | 21.05 |
| Methionine *     | 7.24 B,D    | 8.68 a,A           | 8.36 b,C | 7.24 D | 7.31 B | 9.15 A,C |
| Isoleucine *     | 15.48 D,F   | 19.35 A,C          | 19.64 B,E | 16.15 B | 16.10 D | 17.96 A,C |
| Leucine *        | 13.44 D,b   | 16.31 A,C          | 14.12 B,a | 13.89 D | 14.53 B | 15.58 A,C |
| Tyrosine         | 15.92 D     | 19.07 A,C          | 16.83 B | 16.81 | 17.54 | 18.02 |
| Phenylalanine *  | 19.19 D,b   | 23.66 A,C          | 20.18 b,a | 20.16 D | 20.29 B | 21.63 A,C |
| GABA             | 18.80 A,C   | 16.01 D            | 16.63 B | 15.91 D | 16.16 B | 17.51 A,C |
| Lysine           | 2.02 B,D    | 5.52 A             | 5.43 C  | 4.53 | 4.72 | 5.09 |
| Histidine        | n.d.        | n.d.               | n.d.    | n.d. | n.d. | n.d. |
| Tryptophan *     | n.d.        | n.d.               | n.d.    | n.d. | n.d. | n.d. |

*—essential amino acids; C—control samples; PMF—permanent magnetic field, VMF—variable magnetic field. Statistically significant differences between means (A-F for p ≤ 0.01; a,b for p ≤ 0.05) marked by different letters in the rows.
Three amino acids were identified in green tea infusions, among which seven were essential amino acids. The highest concentration was observed in the case of glutamic acid and theanine. Among all the types of green tea studied, Gyokuro was distinguished by the highest content of nearly all the amino acids identified, especially essential amino acids, except for glutamic acid and tyrosine. The lowest content of amino acids was observed in Bancha tea infusions, which however had the highest concentration of glutamic acid. Statistical analysis confirmed highly significant differences in the content of amino acids between particular types of green tea. In the analysis of the impact of a magnetic field as a factor improving the extraction of amino acids, highly significant differences were observed in the case of the content of threonine, aspartic acid, isoleucine, leucine, phenylalanine, and GABA acid in tests applying a variable magnetic field (VMF) in comparison with samples of the control infusions (C) and infusions prepared using a permanent magnetic field (PMF). In the case of a permanent magnetic field, no statistically significant differences were observed in the content of amino acids in infusions in comparison with control samples (C). In green tea infusions, no proline and methionine were detected, however, they were present in black tea infusions (Table 3). Moreover, all the types of green tea studied were also characterised by a significant content of GABA acid in comparison to other amino acids. Apart from theanine, threonine, and glutamic acid. According to Wang et al. [28] the substances present in tea have a significant impact on health and well-being. GABA is taken as an oral supplement to relieve anxiety, improve mood, reduce symptoms of PMS, and to increase the sense of wellbeing.

In black tea infusions, like green tea infusions, thirteen amino acids were identified, among which five were essential amino acids. Two essential amino acids—histidine and tryptophan—were not detected in the infusions. The highest concentration was observed in the case of glutamic acid and theanine, however, in comparison to green tea infusions, the concentration of the amino acids was lower by 82% and 47%, respectively. Among all types of black tea studied, the highest content of amino acids, apart from threonine, proline and GABA acid, was observed in the case of Darjeeling from India, and the differences were highly statistically significant. The analysis of basic ingredients (Table 1) also indicated the highest content of protein in this type of dried tea. Two other types of black tea contained a similar profile of amino acids. Methionine and lysine were amino acids occurring in the smallest quantities in black tea infusions, especially in English Breakfast Tea. While in the analysis of the impact of a magnetic field as a factor improving extraction of amino acids in tea infusions, highly significant statistical differences were observed in the content of aspartic acid, threonine, glutamic acid, methionine, isoleucine, leucine, phenylalanine, and GABA acid in samples using a variable magnetic field (VMF) in comparison to samples of control infusions (C) and infusions prepared using a permanent magnetic field (PMF). In the case of a permanent magnetic field, no statistically significant differences were observed in the content of amino acids in infusions in comparison with control samples (C). All types of black tea studied were also characterised by an average content of GABA acid (gamma-aminobutyric acid) which was two-times lower on average than in the case of green tea (Table 2).

3.2. Total Amino Acids in Tea

Figure 3 presents the total content of amino acids (AAs) and essential amino acids (essential AAs) in the sample infusions of green and black tea. Figure 4 presents the impact of a permanent or variable magnetic field on the total content of amino acids (AAs) and essential amino acids (essential AAs) in the sample infusions of green and black tea.
When comparing the content of all amino acids in the black and green teas studied, it was found that the tea with the highest content of amino acids was Gyokuro Japanese green tea, in the infusions of which the presence of essential amino acids was observed at a level of 141 mg L$^{-1}$ on average, which constitutes 22% of the total content of essential amino acids in infusions made with this type of tea. In the case of black tea, the highest content of free amino acids was observed in the case of Darjeeling—431.66 mg L$^{-1}$ on average, which was 45% less than in Gyokuro green tea. The difference

**Figure 3.** Total content of amino acids (AAs) and essential amino acids (essential AAs) in the tea infusion samples (mg L$^{-1}$).

**Figure 4.** Impact of a permanent or variable magnetic field on the total content of amino acids (AAs) and essential amino acids (essential AAs) in the tea infusion samples (mg L$^{-1}$). PMF: permanent magnetic field; VMF: variable magnetic field.
as far as essential amino acids are concerned was 60% for green tea. The total content of amino acids in other types of green tea was similar to the other two types of black tea.

A variable magnetic field applied in order to assist extraction caused an increase in the total concentration of amino acids in green tea infusions by 8.5%, while the content of essential amino acids increased by 17% on average. In the case of black tea infusions, extraction using a variable magnetic field increased the content of amino acids by 4.7% on average, and the content of essential amino acids by 12.6%.

It is known that green tea leaves do not undergo fermentation, therefore their chemical composition can vary significantly from the composition of black tea. After the initial evaporation of water, withered leaves are subject to the process of delicate rolling, and then additional drying, sorting and packing. As a result, green tea has a similar chemical composition to fresh tea leaves and it preserves more valuable ingredients than black tea, and infusions have a delicate, slightly spicy taste and fresh spicy or flowery aroma [29]. In studies conducted by Jabeen et al. [30], it was indicated that significant biochemical changes took place during the initial loss of water and rolling, and they may significantly affect the quality of manufactured tea. It was observed that tea leaves lost their moisture most intensely during the first hours after commencing the process of withering; also, the largest differences in the content of selected chemical components were observed then. Moisture content plays an essential role in maintaining the microbiological stability of dried tea. A high moisture content favours the development of microorganisms, and thus the tea shelf life is reduced.

The content of ash is also an indicator of tea quality and depends on numerous factors, including the manner of processing, storage, and interaction of leaves. A high ash content in tea may indicate falsification or unhygienic conditions during withering and rolling of leaves, and the use of worse quality raw materials. It may also indicate high amounts of micro- and trace elements which can increase the quality of tea; therefore, it is also necessary to examine the content of individual mineral components in tea leaves. The ash content of tea is a very valuable feature of its quality [30]. As indicated by many study authors, the manner of processing tea leaves after collecting them has a significant effect in determining the content of free amino acids, and they are considered to be important criteria to ensure tea quality due to their impact on taste, smell, and colour as well as the physiological action of infusions [31]. It has also been proven that theanine, an analogue derivative of glutamic acid, reduces mental and physical stress, and improves mood, concentration, and cognitive functions in a similar manner to caffeine [32]. In the studies conducted by Jabeen et al. [30], an increased amount of amino acids in tea samples subjected to the process of rolling which have lost some of the moisture and elasticity was observed in comparison to freshly harvested tea leaves. According to Yao et al. [31], this fact may be caused by the degradation of proteins into amino acids through peptidase as well as the conversion of sugars into amino acids during the process of withering; this process is positively correlated with temperature until the cells in the plant tissue are deactivated. In their experiments, Jebeen et al. [30] indicated that the total content of free amino acids in tea infusions prepared from samples of fresh tea leaves started from 1.5% and after 23 h of withering increased nearly two-fold. In the next hour of withering, a decrease in the content of free amino acids was observed to the level of approx. 2.5%, which according to the authors is an indicator of the quality and degree of tea processing. Based on a review of research, it can be stated that the concentration of free amino acids both in dried tea and in tea infusions is an extremely important parameter defining their quality. Information can be found in the literature confirming that during the processing of tea leaves a partial conversion of amino acids such as isoleucine, leucine, valine, and phenylalanine to aldehydes takes place, which are responsible for the components of the tea aroma. According to the authors of this kind of research, such a conversion takes place much more frequently in fermented black tea which was subjected to much more extensive high temperature treatment during the drying process than green tea which resulted in the differences in the content of free amino acids in dried green and black tea [33]. In the studies conducted by Kocadagli et al. [34] it was proven that the decaffeination process can reduce the content of free amino acids in tea by more than 20%. Moreover, the authors indicated that the brewing
time and temperature of water impacts the content of free amino acids in tea infusions. According to the authors, during tea brewing, most amino acids are extracted during the first two minutes, and theanine is the dominating amino acid—its content was approx. 30% of the total content of free amino acids in the green and black tea infusions studied. They also indicated that as a result of brewing black tea at a permanent 85 °C placed in the thermostat for 15 min, the total content of free amino acids was 311 mg L\(^{-1}\) while in infusions of the same tea poured with water at 85 °C and brewed at room temperature without thermostat, the content of free amino acids was lower by 15% on average than the first case. In the case of green tea infusions, the tendency was similar; however, the total content of amino acids was lower by approx. 10% than in the case of black tea infusions. In the studies conducted by the authors of this work, an inverse dependency was observed. Moreover, a significantly higher concentration of free amino acids was obtained in green tea infusions (564.70 mg L\(^{-1}\)) than black tea infusions (371.35 mg L\(^{-1}\)); however, extraction was conducted at 100 °C, the tea was of high quality and an amino acid analyser with postcolumn derivatization was used for the determination of the amino acids. According to the authors of other studies, determination of amino acids in water solutions using the HPLC technique may result in numerous difficulties, most of all due to pure linearity, low recovery rates, and high limits of detection and quantification [35]. Due to the lack of a suitable chromophore, it was necessary to label the amino acids using a labelling reagent such as dabsyl chloride, \(o\)-phthalaldehyde (OPA), and phenylisothiocyanate. Such a situation involves pre-column or postcolumn derivatization and detection using a fluorescence or diode array detector (DAD). However, clear chromatograms are very difficult to obtain during analysis of the composition of free amino acids in tea infusions [15,36]. The internal high-temperature reactor used in the studies conducted by the authors of this work with a coiled capillary for the colour reaction of the amino acid-ninhydrin complex coupled with high temperature postcolumn derivatization of ninhydrin allowed free amino acids to be precisely determined even in the case of low concentrations (sykam.com). Wang et al. [37] additionally applied the solid phase extraction (SPE) analytical technique in order to increase the precision of amino acid determination in green tea, black tea, and oolong tea infusions. As a result, they indicated the highest content of free amino acids in green tea infusions and an approx. 40% lower concentration in the case of black tea infusions in comparison with green tea infusions, which is compliant with the results obtained in this work. According to Wang et al. [28], green tea is a rich source of numerous amino acids important for the human body, such as glutamic acid, aspartic acid, and phenylalanine, and their content significantly exceeds the content of the amino acids in fermented tea. The authors of these studies also draw attention to the presence of non-protein GABA amino acids which together with theanine can be considered to determine the taste and quality characteristics for these types of tea.

Therefore, it is necessary to undertake studies both in the field of optimisation of the tea manufacturing process as well as monitoring the quality of the tea available on the market. It would also be useful to seek effective extraction methods and the selection of the optimal parameters to brew tea to obtain infusions which are the most valuable for human health.

4. Conclusions

A higher content of free amino acids was observed in green tea infusions than in black tea infusions. A statistically significant improvement in the level of free amino acids was observed after application of extraction assisted by a variable magnetic field with induction at 100 mT and a frequency of 50 Hz. A variable magnetic field applied as a factor assisting extraction resulted in an increased concentration in the total number of amino acids in green tea infusions by 8.5%, while the content of essential amino acids increased by 17% on average. In the case of black tea infusions extraction using a variable magnetic field increased the content of amino acids by 4.7% on average, and the content of essential amino acids by 12.6%. Extraction using a variable magnetic field for tea infusions may constitute a good solution to assist traditional water extraction methods for research purposes.
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