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HEALTH-PROMOTING PROPERTIES OF BIOACTIVE COMPOUNDS OF TEA AND THE INFLUENCE OF METHOD OF INFUSION PREPARATION AND TIME ON THEIR CONTENT®

Właściwości prozdrowotne związków bioaktywnych występujących w herbacie oraz wpływ sposobu i czasu parzenia na ich zawartość®

Tea is one of the most consumed non-alcoholic beverages in the world, not only because of its unique taste and aroma, but also health-promoting properties resulting from the presence of bioactive compounds. The main ingredients of tea which are attributed to have beneficial health effects are polyphenols. The content of bioactive compounds in tea depends on the particular type of tea, way of leaves processing, as well as method and time of infusion preparation. The aim of the article is to characterize the health-promoting properties of bioactive compounds found in tea, as well as to determine the influence of the method and time of infusion preparation on their content in tea infusion.

Key words: tea, bioactive compounds, antioxidant activities.

Herbata jest jednym z najczęściej spożywanych napojów bezalkoholowych na świecie, nie tylko ze względu na swój unikatowy smak i zapach, lecz także właściwości prozdrowotne wynikające z obecności związków bioaktywnych. Głównymi składnikami herbaty, którym przypisuje się korzystne działanie zdrowotne są polifenole. Zawartość związków bioaktywnych w herbacie jest zależna od konkretnego rodzaju herbaty, sposobu jej produkcji oraz metody i czasu parzenia. Celem artykułu jest scharakteryzowanie właściwości prozdrowotnych związków bioaktywnych występujących w herbacie, jak również określenie wpływu sposobu i czasu parzenia na ich zawartość w naparze herbaty.

Słowa kluczowe: herbata, związki bioaktywne, działanie antyoksydacyjne.

INTRODUCTION

Tea is one of the most frequently consumed nonalcoholic beverages worldwide [36]. Due to its unique taste and aroma, as well as health-promoting properties tea is currently gaining more interest and popularity [13,32]. According to the report of Food and Agriculture Organization of the United Nations (FAO) world tea consumption increased annually by 4.5 percent over the decade to 2016 and the consumption of black tea is supposed to grow at 2.5 percent annually to 2027 [25]. The global consumption of different tea types vary depending on the region, as black tea is predominantly consumed in Western countries [7], green tea is favoured in Asian countries [18] and oolong tea is typically consumed in China [29].

Tea is prepared from the processed leaves of *Camellia sinensis* and based on the complex production processes, flavor and aroma six different tea types may be distinguished – green, white, yellow, oolong, black and dark [63]. According to the different degrees of fermentation, teas may be categorized as non-fermented (green and white teas) [59], slightly fermented (yellow and oolong teas) [77] and fermented (black and dark teas) [31]. Among these types of tea, dark tea is unique, as it undergoes a microbial fermentation [79]. The manufacturing process of green tea aims to prevent the polyphenols oxidization by polyphenol oxidase, which naturally occurs in tea leaves. Therefore, polyphenol oxidase is inactivated during firing or steaming [47]. As a result, green tea retains the highest level of polyphenols due to its minimal oxidation, comparing to teas in which partial or full oxidation take place [42]. Although yellow tea is similar to green tea, it is characterized by higher total soluble sugar content, as a result of an additional fermentation step, which removes grassy smell being typical for green tea [35,70]. In black tea, during the chemical process of fermentation polyphenols are oxidized

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to water-soluble oxidation products, such as theaflavins and thearubigins, which provides the aroma, taste and black color of this type of tea [45]. Green tea and black tea are the two most consumed types of tea worldwide [25].

The aim of the article is to characterize the health-promoting properties of bioactive compounds found in tea, as well as to determine the influence of the method and time of infusion preparation on their content in tea infusion.

BIOACTIVE COMPOUNDS IN TEA

Tea contains approximately 30% of soluble ingredients which may vary, depending on different factors, such as harvesting time and harvesting conditions, climate, cultivation practices and technological processes during tea production [24,67,68,74]. Tea contains nearly 4 000 bioactive compounds, including polyphenols, alkaloids, polysaccharides, pigments, saponins and free amino acids [4,63], however, the share of specific bioactive compounds may differ between various types of tea [63].

The main components of tea are polyphenols which constitutes up to 20–35% of tea's dry weight [75]. Polyphenols are plant metabolites which are categorized into following subclasses – flavonoids, flavanols, flavonols, flavones, isoflavones, flavanones and anthocyanidins [20], however their content may be dependent on the particular type of tea. Green tea is reported to contain higher level of phenolic compounds, comparing to black tea [5] and is also best studied in terms of its beneficial health effects [33]. The major flavonoids which are present in green tea are epicatechin, epicatechin gallate, epigallocatechin and epigallocatechin gallate [51]. In black tea, these flavonoids are present in lower amounts, as they are partially converted during fermentation process to condensation products, such as theaflavins and theaflagallins [62]. A number of studies indicate that polyphenols are mainly responsible for the vast range of its beneficial health effects, including antioxidative [2, 76], anti-inflammatory [14, 56], anticancer [26, 44], antibacterial [46] and hepatoprotective [60] actions. Some studies indicate that green tea catechins modulate epigenetic processes, as they reverse DNA methylation of tumor suppressor genes [74]. Flavonoids, such as catechin, epicatechin and epigallocatechin-3-gallate are found to be effective in cardiovascular diseases prevention due to lowering cholesterol level, improving endothelial function and alleviating oxidative stress [30, 78]. The antioxidant effects of tea infusions are attributed mainly to the polyphenols. It was shown that tea polyphenols are effective scavengers of reactive oxygen species which are generated due to oxidative stress [12]. It was also indicated that tea extract prevents damage of cellular DNA *in vitro* which was caused by arsenic-mediated oxidative stress [1]. However, it must be emphasized that due to the differences in bioavailability of polyphenols, in vivo antioxidant activities cannot be simply extrapolated from their in vitro antioxidant properties [27].

Tea contains substantial amounts of alkaloids, mainly purine alkaloids, such as caffeine, theobromine and theophylline which are responsible for tea's stimulating effect on the body and nervous system [16, 43]. A cup of tea may contain up to 100 mg of caffeine, however, on average, green tea contains 35 mg of caffeine and black tea – 70 mg [10]. Caffeine, called theine due to its origin and its metabolites increase the secretion of neurotransmitters which reduce fatigue and drowsiness and improve concentration. As a result, tea consumption increases the ability to perform mental and physical work, while reducing the feeling of mental and physical exhaustion [43].

Polysaccharides are another bioactive component found in tea which are a nonstarch protein-bound acidic polysaccharides [15]. There is evidence that tea polysaccharides may prevent obesity development [68, 71]. In the study of Wu et al. [69] oolong tea polysaccharides combined with polyphenols were administrated to rats fed with high-fat diet. It was indicated that tea polysaccharides combined with polyphenols showed the highest anti-obesity effect in terms of body weight gain. Therefore, these two bioactive compounds may be beneficial regarding obesity prevention. Moreover, tea polysaccharides attenuate oxidative stress through scavenging of free radicals and enhancing antioxidase enzymes activities [23]. Another health benefit which may be attributed to tea polysaccharides is antidiabetic activity, as in the study of Ren et al. [55] it was revealed that tea polysaccharides ameliorated insulin resistance and hepatic oxidative injury in mice.

Pigments, such as theaflavins, thearubigins, and theabrownins, which are the products of catechins oxidation during fermentation process, are typical for black, oolong and dark teas [63, 64]. Tea pigments have been recognized as one of the bioactive compounds which are responsible for health-promoting properties of tea, such as anticancer [49], hepatoprotective [66] and anti-inflammatory, however, the antioxidant activity of pigments may be lower than catechins [53].

THE INFLUENCE OF BREWING TEMPERATURE ON THE CONTENT OF BIOACTIVE COMPOUNDS IN TEA

Despite differences in tea processing, the method of tea drinking is similar and it implies steeping tea leaves for a few minutes in hot water, at a temperature 70–100°C, depending on tea type [3, 38]. Typically, green tea is prepared by steeping tea leaves in hot water at 80–90°C for about 3-4 minutes, while white tea is usually brewed at 60°C for 5 minutes [50]. However, the way of drinking tea may vary by specific countries. In Japan green tea is usually steeped in hot water for about 2 minutes and the infusion is used two to three times, while in China tea is typically steeped in hot water and the same tea leaves are reused up to seven times [40, 65]. In the United Kingdom, Canada and Ireland black tea is prepared using boiling water and it is often consumed with milk and sugar [65]. Despite typical methods of infusion preparation, in recent times, alternative methods, such as steeping tea with cold water (4°C or room temperature) or steeping tea leaves using hot water followed by addition of ice are also attracting interest [19, 38].

It is emphasized that the method of infusion preparation, including temperature of water, infusion time and number of extractions influence polyphenol content and antioxidant capacity of the tea infusion [34, 52, 61], as well as it may affect sensory properties [39]. In the study of Komes et al.

[34] it was stated that maximum extraction efficiency of phenolic compounds was obtained while brewing green tea at 80°C. The study of Saklar et al. [58] analyzed the influence of different steeping conditions (temperature ranging from 75 to 95°C and time ranging from 1 minute to 45 minutes) on catechins content in green tea. It was found that brewing tea at 85°C for 3 minutes was optimal in terms of epigallocatechin gallate content in green tea infusion (50.69 mg/100 ml), which is in accordance with commonly recommended steeping conditions of this type of tea. Safdar et al. [57] studied 10 different methods of preparing green tea, including brewing infusion at 25, 52, 75 and 80°C. The method of preparing tea affected the chemical composition of infusions. Infusions brewed using water at room temperature contained less tannins and more saponins, comparing to those obtained by traditional brewing. In infusions which were brewed over 20 minutes, the presence of proteins was detected, which were not present in infusions obtained as a result of brewing for up to 3 minutes [57]. In order to maximize optimal extraction of bioactive compounds from green tea it is advised to brew it at moderate temperatures, as at high temperatures exceeding 90°C polyphenols are destroyed [6, 58].

Steeping tea leaves using cold water may maximize health effects and sensory appeal of tea infusion [11, 19, 28, 41, 54, 72]. Castiglioni et al. [11] studied the effect of steeping conditions on antioxidant activities of green and white teas. It was indicated that the maximum extraction efficiency of the phenolic compounds from tea samples was obtained while teas were brewed with cold water for 120 minutes and with hot water for 90 minutes, however, the extraction was higher in cold than in hot infusions only in the case of teas from large leaves. In the study of Damiani et al. [19] it was shown that white teas brewed at room temperature for 120 minutes were characterized up to 70% more phenols, flavonoids and catechins content and antioxidant capacity, comparing to those which were brewed at 70°C for 7 minutes. Overall, this beneficial effect of brewing tea with cold water may be dependent on the certain type of tea, as in the study of Hajiaghaalipour et al. [28] it was indicated that the highest antioxidant activity for white tea was observed in prolonged hot and in some assays prolonged hot and cold extracts, while for green tea the highest activity was in prolonged cold brewing. Tea infusions prepared with cold water are also stated to contain lower amounts of caffeine and reduced bitterness than tea infusions made using hot water [72]. Additionally, in the study of Lin et al. [41] it was stated that cold brewing provides lighter color of tea infusion and higher sensory-rated infusions.

Although brewing tea using cold water seems to be a promising method in order to maintain high content of bioactive compounds in tea infusions, it requires longer infusion time, comparing to brewing tea using hot water [38]. Therefore, a novel modification has been proposed in order to overcome it. Lantano et al. [38] introduced an additional step after steeping tea with hot water, including ice addition, which enables to avoid slow cooling process causing changes in the bioactive compound content. Even if the antioxidant activity of hot-iced tea was lower than in the cold one, the amount of catechins was higher in hot-iced tea.

THE INFLUENCE OF BREWING TIME ON THE CONTENT OF BIOACTIVE COMPOUNDS IN TEA

It is well known that not only the temperature, but also the time of tea infusion influence the extraction of bioactive compounds, as well as antioxidant capacity [11, 37, 48, 50, 52, 54]. Therefore, monitoring these parameters should be a matter of great importance in order to obtain all health benefits of tea [52]. Most of the available studies show that longer brewing time has a beneficial effect on the polyphenol content and antioxidant capacity of tea infusions [8, 17, 21, 22, 52]. Research of Pérez-Burillo [52] revealed that antioxidant capacity of white tea gradually increased in the linear manner with infusion time and temperature. In the study of Dmowski et al. [22] it was stated that the average polyphenols content in the tea samples ranged from 67,70 mg gallic acid equivalent (GAE)/100 ml (3-minute infusions) to 239,57 mg GAE/100 ml (15-minute infusions), so the infusion time was relevant factor polyphenol content. Similar results were obtained by Błaszak et al. [8], as the higher amount of polyphenolic compounds was contained in infusion of black tea leaves brewed at 80°C for 5 minutes, comparing to infusion of black tea which was brewed at 80°C for 3 minutes (24,6 mg GAE/100 ml; 23,5 mg GAE/100 ml, respectively). The research of Dmowski et al. [21] determined the total polyphenol content in black teas, taking into consideration the brewing time and origin of tea [5]. It was indicated that the highest phenolic content was stated in the black tea from Sri Lanka. Interestingly, the longer time of tea brewing was, the higher the polyphenol content was recorded. Braud et al. [9] demonstrated that a 5 minute infusion time is sufficient to reach maximal bioavailability of phenolic compounds and caffeine in tea. Further increase of the brewing duration (15 or 30 min) cause no change, or even a decrease, of their concentrations. These results are at variance with those obtained by Cleverdon et al. [17], as in case of green tea, 10-minute infusion was characterized by significantly higher total polyphenol content than 5-minute infusion.

THE INFLUENCE OF NUMBER OF EXTRACTIONS ON THE CONTENT OF BIOACTIVE COMPOUNDS IN TEA

Tea brewing may be performed by reusing the same tea leaves, as a number of bioactive compounds is retained, which have not been exhausted [34, 61]. In the study of Komes et al. [34] it was revealed that during a second and third brewing of green tea, which were performed at the temperature of 80°C for 3 min, the antioxidant activity increased by 25%, comparing to the first infusion. The research of Yang & Liu [73] investigated the influence of numbers of extractions on phenolic and flavonoid contents in different types of teas. It was observed that in general green tea contained the highest level of phenolics and flavonoids, comparing to oolong and black teas. Moreover, the first brewing was characterized by the highest content of bioactive compounds and the fourth brewing by the lowest content. Another study performed by Sharpe et al. [61] aimed at assessing the effect of six successive green tea infusions at 60°C for a period of 5 minutes on

antioxidant capacity. It was observed that certain types of teas did not release significant levels of bioactive compounds apart from the first infusion. However, some teas continued to release catechins within six brews or more. Therefore, it seems that another factors, such as harvest season or form of tea (bagged vs. loose-leaf) may play role in the ability of tea to be reused.

CONCLUSION

Tea is currently gaining great interest, not only because of its sensory properties, but also its health-promoting properties. The beneficial health effects of tea are related to the presence of many bioactive substances, including polyphenols, alkaloids, polysaccharides, pigments and saponins. These compounds have antioxidant, anti-inflammatory, anti-cancer, antibacterial and hepatoprotective properties, and can also be used in the prevention of obesity and cardiovascular diseases. Caffeine found in tea stimulates the nervous system, reducing fatigue and increasing concentration. The content of the bioactive compounds in tea depends on the temperature and time of tea brewing, as well as the number of extractions of the tea leaves. Most of the available studies show that longer brewing time has a beneficial effect on the polyphenol content and antioxidant capacity of tea infusions. It is indicated that the temperature of 85°C is optimal to obtain the maximum amount of polyphenolic compounds in the infusion of green tea, however, there are indications that using of cold water in the tea preparation may also have a positive effect on the content of bioactive compounds in the infusion. Preparing tea several times using the same leaves may result in further extraction of bioactive compounds, however, research results in this field are inconclusive and it is assumed that other factors such as the harvest season and the form of the tea (bagged or loose-leaf) may determine the possibility of further extracting bioactive compounds from the infusion.

PODSUMOWANIE

Herbata cieszy się obecnie dużym zainteresowaniem, nie tylko ze względu na jej właściwości sensoryczne, lecz również właściwości prozdrowotne. Korzystne działanie zdrowotne herbaty związane jest z obecnością wielu substancji bioaktywnych, w tym polifenoli, alkaloidów, polisacharydów, pigmentów i saponin. Związki te wykazują działanie antyoksydacyjne, przeciwzapalne, przeciwnowotworowe, antybakteryjne, hepatoprotekcyjne, jak również mogą być wykorzystywane w prewencji otyłości i chorób sercowo-naczyniowych. Kofeina znajdująca się w herbacie działa stymulująco na układ nerwowy, redukując uczucie zmęczenia i zwiększając koncentrację. Zawartość związków bioaktywnych w herbacie jest zależna od temperatury i czasu przygotowania naparu, jak również liczby ekstrakcji liści herbaty. Większość dostępnych badań wskazuje, że dłuższy czas parzenia wpływa korzystnie na zawartość polifenoli i zdolności antyoksydacyjne naparów herbaty. Wskazuje się, że temperatura wynosząca 85°C jest optymalna do uzyskania maksymalnej ilości związków polifenolowych w naparze zielonej herbaty, jednakże istnieją przesłanki, że używanie zimnej wody do przygotowywania herbaty może również korzystnie wpływać na zawartość związków bioaktywnych w naparze. Kilkukrotne przygotowywanie herbaty przy użyciu tych samych liści może powodować dalszą ekstrakcję związków bioaktywnych, jednakże wyniki badań z tego zakresu są niejednoznaczne i przypuszcza się, że inne czynniki, takie jak pora zbioru liści herbaty oraz forma herbaty (w torebkach lub liściasta) mogą determinować możliwość dalszej ekstrakcji związków bioaktywnych z naparu.

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