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ORIGINAL PAPER

ANTIOXIDANT CAPACITY AND CHOLINESTERASE INHIBITING PROPERTIES OF DIETARY INFUSIONS WITH *HUMULUS LUPULUS**

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Abstract

The aim of the study was to evaluate the possibility of using hop leaves and cones as a component of functional teas. The recipes for teas with the addition of cones and leaves of the common hop cultivar Magnum were developed. Mixtures for the preparation of infusions were made in combination with white mulberry, mint and yellow tea leaves. The infusions were prepared from the selected mixtures, and then they were evaluated in terms of total polyphenol content and free radical scavenging with a DPPH assay. Moreover, the chelating activity and the ability to reduce ferric ions were determined. The ability of extracts to act as cholinesterase inhibitors was investigated. The sensory profile evaluation of the samples was carried out. It was shown that the prepared teas were rich in phenolic compounds and exhibited various antioxidant properties. The use of hop cones and leaves allowed us to obtain teas which had the ability to chelate and reduce iron ions, and also inhibited the activity of cholinesterases. The most effective inhibition of the activity of acetylcholinesterases was noted for the samples containing hop cones, whereas in the case of butylcholinesterases the highest effectiveness was observed in the samples containing hop leaves. The use of hop cones and leaves means that a new range of teas with characteristic sensory and functional properties can be made.

Keywords: hops, functional food, polyphenols, antioxidant capacity, neurodegenerative disorders, cholinesterase inhibitors.

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INTRODUCTION

Common hop (*Humulus lupulus* L.) is a climbing plant from the *Cannabaceae* family. Hops are now widely grown in all temperate regions of the world (Mongelli et al. 2016). Previous studies demonstrated that both hop cones and leaves contain, *inter alia*, resins, essential oils, proteins, polyphenols, lipids, waxes as well as vitamins and minerals. The proportion of these compounds in the anatomical parts of hop varies, and cones in particular are a source of resins containing acids responsible for giving beer a bitter taste. The bitter acids in hops are prenyl derivatives of phloroglucin, and include humulons (α-acids) and lupulons (β-acids) (Dresel et al. 2016). The cones also contain essential oils secreted by lupulin glands (myrcene, cariofilene, humulene and farnesene, terpenic alcohols such as linalol and geraniol) (Almaguer et al. 2014). The second most significant group of compounds contained in both hop cones and leaves are polyphenols. The most important hop polyphenols include prenyl chalcones (xantohumol, desmethylxantohumol), which produce isomeric flavanones (isoxantohumol, 8-prenylonaryngenin) (Jaskula-Goiris et al. 2018). The most important prenylated chalcone in terms of concentration and biological activity is xantohumol (Gołąbczak, Gendaszewska-Darmach 2010).

Hop leaves are not commonly used in the food industry but, similarly to cones, they have components with potentially health-promoting properties. It was shown that they contain volatile compounds, chalcones and gentian acids (Abram et al. 2015). The main components of essential oils of hop leaves are α-humulene and β-caryophyllene. It is believed, however, that the concentration of active compounds in leaves is lower than in cones (Knez Hrnčič et al., 2019).

The cones of female hop plants are mainly used as an ingredient for the brewing industry (Abram et al. 2015). In the literature, there are reports on the possibility of hops being used as an ingredient of teas. The literature data indicate that a hop cone infusion has sedative, diuretic, diastolic (gastrointestinal), analgesic, strengthening, anti-inflammatory and antibacterial (skin lesions) effects (Lamer-Zarawska et al. 2007). New reports also indicate possible preventive and therapeutic effects in the case of neurodegenerative diseases (Kobus-Cisowska et al. 2019). In modern medicine, synthetic acetylcholinesterase and butyrylcholinesterase inhibitors are used to treat symptomatic dementia, but their use is often associated with side effects, which could be minimized if therapy with phytocompounds was chosen (Mohammad et al. 2017). It is believed that plant polyphenols contribute to inhibition of inflammation, thus improving the oxidative-antioxidative balance in the organism (Gelber et al. 2012). An important aspect is the ability of components of hop cones and leaves to chelate and reduce iron ions. Under normal conditions in the body, iron is transported and stored by specific proteins (transferrin, ferritin). This prevents the reaction of free iron ions

with reactive oxygen species (ROS) (Imam et al. 2017). Ferrous ions participating in the Fenton reaction generate •OH, which in turn easily reacts with lipids causing their peroxidation. This may be one of the causes of many cardiovascular and neurodegenerative diseases. Therefore, it is important to search for substances with the ability to chelate and reduce transition metal ions. Moreover, it is believed that excess iron in the body favors the formation of active oxygen species, which, leading to oxidative stress and inflammation, favor cell damage, including nerve cell damage (Pilo, Angelucci 2018). A high iron concentration accompanied by excessive oxidative stress may be one of the causes of neurodegenerative diseases (Medeiros et al. 2016). So far, the effectiveness of chelating compounds in the form of drugs has been taken advantage of, although studies on animal models prove the effectiveness of so-called phytochelators contained in plant raw materials (Kontoghiorghe et al. 2015).

The nutritional importance of hops has been growing in recent years. Due to the presence of active compounds, pro-health effects can be expected in terms of chelating and reducing ions of metals. Taking into account the reports on properties of hops, the aim of the study was to assess the possibility of adding hops as an ingredient of functional teas with antioxidant, chelating and iron ion reducing properties.

MATERIAL AND METHODS

Raw materials

Leaves and cones of common hop (*Humulus lupulus* L.) of the cultivar Magnum were used as the material for the study. Hop leaves and cones were obtained from a hop plantation located in Malice (Kujawsko-Pomorskie Voivodeship, Kcynia: 52°59′52.6″N 17°31′20.6″E). The cones were harvested at the turn of August and September, while the leaves were picked in August and after the harvest they were lyophilized. The cones were characterized taking into account the determination of the basic chemical composition: fat 34.83%, ash 4.52%, protein 19.41%, fiber 23.41%. The leaves had the following composition: fat 4.34%, ash 12.19%, protein 8.11%, fiber 32.43%.

The hop cones and leaves were crushed in a Grindomix GM 200 from Retsch (Haan, Germany) for 15 s at a speed of 500 rpm at 21°C to a particle size of 0.5 - 0.9 mm. Other raw materials such as yellow tea, white mulberry and mint leaves were purchased from retail producers (yellow tea leaves, PHU FAJ&KA producer), dried mint leaves (Agnex producer), and white mulberry leaves, *Morus alba* L, a variety of Wielkolistna Żółwińska, were obtained from a plantation of the Institute of Natural Fibers and Herbal Plants in Poznań, at the Experimental Plant Pętkowo in Środa Wielkopolska (52°12″ N 17°15″ E).

Extraction

The tea was subjected to water extraction. The extract was obtained using the three-fold extraction method. A total of 1000 mL of water (400, 300 and 300 mL, respectively) at 85°C was poured into a test portion of 50 g of dried material and extracted each time for 10 minutes. The extraction was repeated three times, each time the extract was filtered, centrifuged (2697 x g, 15 min), each of the fractions was decanted and filtered (Whatman 1 : 11 μm), and the obtained supernatants were combined and lyophilized according to the method described earlier (KOBUS-CISOWSKA et al. 2019)

Determination of antioxidant properties by Folin-Ciocalteu's method

The determination was performed according to the method described by CHEUNG et al. (2003). The assay relies on the transfer of electrons in an alkaline medium from phenolic compounds, which leads to formation of blue complexes to be determined spectroscopically (Metertek SP-830, Taiwan) at a wavelength of 765 nm. The results were presented as equivalent to the concentration of mg gallic acid (GAE) g^{-1} of d.m. in the extract. All assays were performed in triplicate.

Determination of antioxidant properties using the DPPH radical method

The determination was performed with the method described by KOBUS-CISOWSKA et al. (2019*b*). The method relies on a spectrophotometric (Metertek SP-830, Taiwan) measurement of the color of a reaction mixture, in which, depending on the antioxidant capacity of the extract under study, free azo radicals generated by the methanol solution of DPPH (1,1-diphenyl-2-pyrylhydrazil) were scavenged. Absorbance at 517 nm was measured after 30 min of incubation at room temperature without light access. All assays were performed in triplicate. The scavenging effect on the DPPH radical of the samples was calculated as the Trolox (Tx) equivalent's antioxidant capacity from the calibration curve: $y = 721.22x - 2.3246$, $r^2 = 0.986$. The results were presented as equivalent to the concentration of μM Tx of dry matter in the extract.

Chelating properties

The principle of the method was to create a complex of an antioxidant with iron (Fe^{2+}) by attaching the metal ion to the antioxidant molecule containing a free electron pair using a coordination bond (TANG et al. 2002). The color change of the reaction system was spectrophotometrically recorded at 562 nm, and the chelating activity was calculated from the formula taking into account the value of absorbance and using the determined iron chelating capacity (ChA), specific sample absorbance (E_p), zero sample absorbance (E_0) and control sample absorbance (E_k). All assays were performed in triplicate.

Reducing properties

Reducing properties were determined according to the method described by KOBUS-CISOWSKA et al. (2019b), which consisted of a spectrophotometric measurement at a wavelength of λ = 700 nm of the absorbance of Prussian blue resulting from the reaction of Fe (II) derived from the reduction of Fe (III) contained in $K_3Fe(CN)_3$ with ferric chloride (III). The results were expressed as absorbance. All assays were performed in triplicate.

Cholinesterase inhibition

The modified spectrometric method developed by ELLMAN et al. (1961), which was described by KOBUS-CISOWSKA et al. (2019), was used to measure the activity of the extracts as AChE and BChE inhibitors. A POLARstar Omega (BMG LABTECH, Germany) plate reader was used for measurements of 96-well plates of the maximum volume of 300 µL. The hydrolysis of acetylthiocholine/butyrylthiocholine caused a color change. The absorbance of the enzymes was measured at a wavelength of 412 nm, ten minutes after pipetting on a microplate. The reaction mixture containing 0.1 mL of 0.3 mM 5,5-dithio-bis-(2-nitrobenzoic acid) (DTNB, Sigma Aldrich, Germany), 10 mM NaCl and 2 mM $MgCl_2$ $6H_2O$ solution, 0.575 mL 50 mM Tris-HCl bu er (pH = 8.0), 25 L of 0.28 units mL^{-1} AChE/BChE (Sigma Aldrich, Germany), and 0.2 mL of the tested extract was analyzed at a temp. of 22°C. The measurement was conducted 20 min (BChE) or 60 min (AChE) after adding all ingredients into a microplate. The blank sample contained Tris-HCl buffer instead of the tested extract. A positive-negative control was applied, consisting of 90.7 M eserine instead of the tested extract. All samples were analyzed in eight independent repeats. The inhibitory activity of each enzyme was calculated with the use of a calibration curve. The calibration curves were prepared using eserine as the standard in concentration ranges between 0.09-6.10 M for AChE and 0.09-8.57 M for BChE. The linearity of the curve coefficient – r2 equaled 0.97 for AChE and 0.95 for BChE. All assays were performed in triplicate.

Sensory evaluation by means of a profile assessment method

Sensory evaluation of the samples was carried out in a sensory laboratory meeting the requirements of the PN-EN ISO 8589:2010 standard. For detailed sensory characteristics of these samples, the method of quantitative descriptive analysis, i.e., sensory profiling, was used, which was performed by a team of 20 people specially trained for this purpose. The following unit qualitative characteristics were assessed: color (clear, straw, brown, green), taste (sweet, sour, bitter, fruity, tang, grassy, foreign), smell (fruity, earthy, sweet, sour, foreign, intensive). The intensity of each quality note was determined by means of a 10-cm unstructured linear scale with appropriate edge markings. The results obtained were replaced by numerical values expressed in contractual units.

Statistical analysis

All values means of two independent experiments performed in three repetitions. Data were analyzed using one-way analysis of variance ANOVA ($p<0.05$) to determine differences between the mean values determined for the tested samples, as well as the Tukey's multiple-range test. The data were analyzed statistically with Statistica PL 13.1 software (Statsoft, Poland)

RESULTS

Tea was made using cones and leaves of the Magnum hop cultivar and yellow tea, white mulberry and mint leaves (Table 1).

Table 1

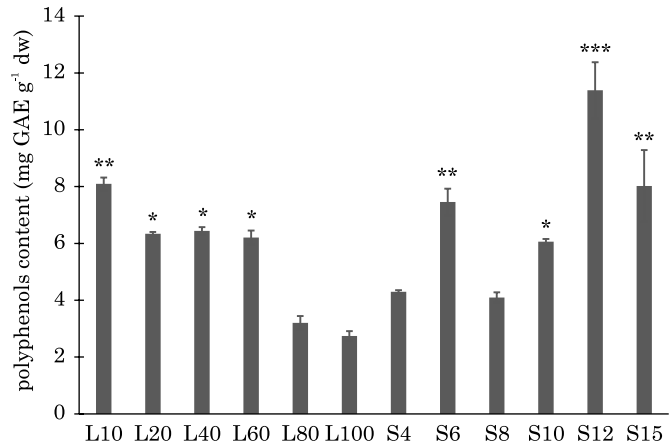
List of prepared samples with specified content of raw materials

	Raw materials content (%)				
Sample code	mulberry	mint	yellow tea	hop leaves	hop cones
L0	33.3	33.3	33.3		0
L100	0	0	0	100	0
L80	6.66	6.66	6.66	80	0
L60	13.33	13.33	13.33	60	0
L40	20	20	20	40	0
L20	26.66	26.66	26.66	20	0
L10	30	30	30	10	0
S15	28.33	28.33	28.33	0	15
S12	29.33	29.33	29.33	0	12
S10	30	30	30	0	10
S8	30.66	30.66	30.66	0	8
S6	31.33	31.33	31.33	0	6
S4	32	32	32	0	4

* mean value was significantly different ($p\leq0.05$). between the samples (ANOVA)

Among the tested samples, the highest content of polyphenols was found in sample S12 containing 11.4 mg of gallic acid g^{-1} of the product; the content of polyphenols ranged from 2.7 to 8.1 in teas containing hop leaves and from 4.1 to 11.4 mg of gallic acid g^{-1} of the product in teas containing hop cones. The lowest polyphenol content of 2.74 mg of gallic acid g^{-1} was determined in sample L100 (Figure 1).

The highest antioxidant activity was observed in sample L80, being slightly lower in sample L60, the activity of which was 5.1 and 5.0 μM Tx g^{-1} of d.m., respectively. Teas containing hop leaves showed higher anti-

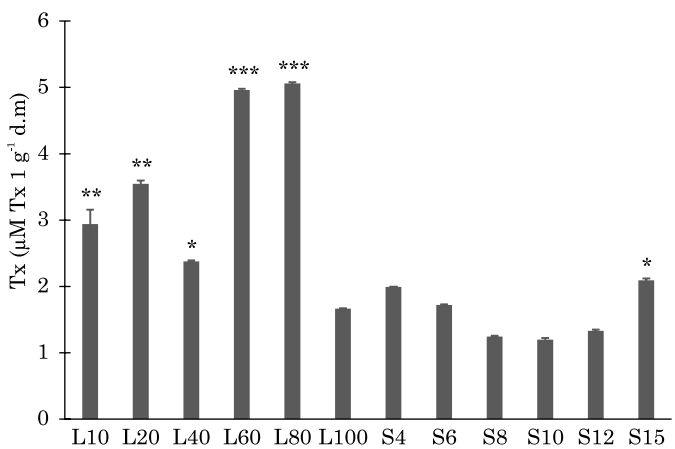


* mean value was significantly different ($p \leq 0.05$) between the samples (ANOVA)

Fig. 1. Polyphenol content in infusions with *Humulus lupulus*

oxidant activity in the range of 1.7 to 5.1 5 μM Tx g^{-1} d.m., whereas in the case of teas containing hop cones these values were in the range of 1.3 to 2.1 μM Tx g^{-1} d.m. (Figure 2).

It was found that the preparations had a chelating ability, which depended both on the amount of hops and on the anatomical part of the plant (Figure 3). The highest chelating activity was found for sample L20. Among the extracts studied, the highest amount of ferrous ions, i.e., from 57.17% in the case of L40 to 63.87% in the case of L20, were chelated by extracts with the addition of hop leaves. Among the extracts with hop cones, the highest metal chelating ability was found for S4 (47.27%).



* mean value was significantly different ($p \leq 0.05$) between the samples (ANOVA)

Fig. 2. Antioxidant activity of infusions with *Humulus lupulus*

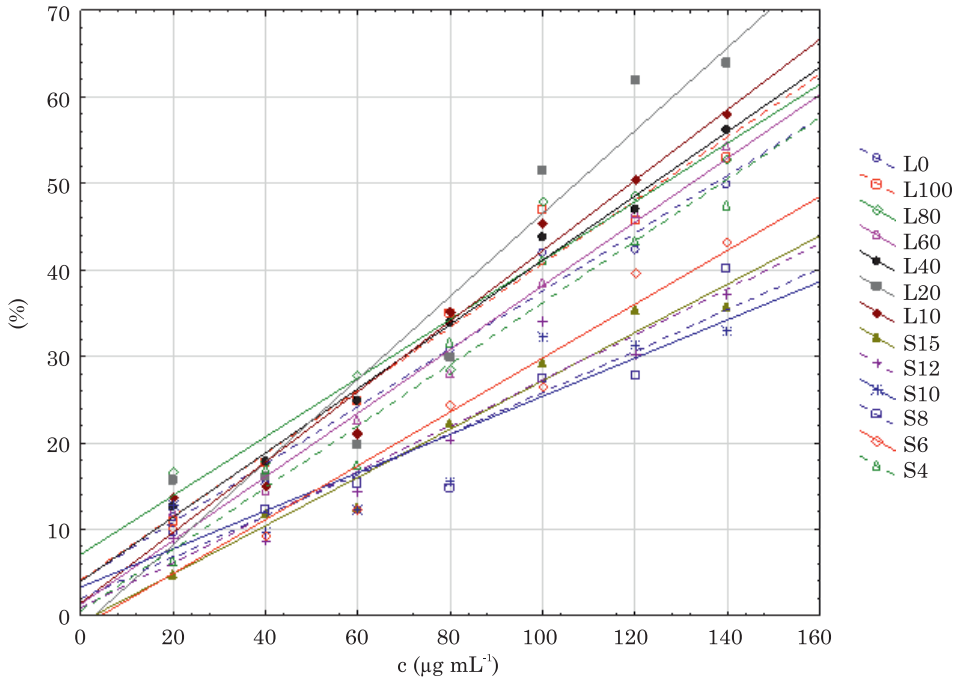


Fig. 3. Chelating activity of infusions with *Humulus lupulus*

In the study, extracts in the range between 20 - 140 µg ml^{-1} (20, 40, 60, 80, 140 µg ml^{-1}) were tested to plot a curve illustrating concentration-dependent activity variability. As a result of the tests, it was found that increasing the concentration of extracts from 40 µg mL^{-1} to 100 µg mL^{-1} had the greatest effect on the chelating activity, by raising it threefold.

Infusions with added hops were characterized in terms of the ability to reduce Fe (III) to Fe (II). This illustrates the antioxidant activity expressed by the virtue of its ability to transfer single electrons. This reaction is associated with an increase in the negative charge and, as a result, a decrease in the degree of oxidation (Figure 4).

The extracts showed a reducing capacity depending on the amount of hops in the infusion. The highest reducing capacity was observed in extracts containing hop cones, and the lowest one was in extracts containing hop leaves. The highest value of absorbance, indicating a high ability to reduce ferric ions, was found for S4 extract at the highest concentrations, while the S12 sample at the lowest concentration sample was characterized by higher absorbance. The reducing activity in hop cone extracts was by 9% to 58% higher than in leaf extracts. Extracts with the addition of hop leaves showed statistically significantly lower activity, and this activity was decreasing in the following order: S4 > S6 > S8 > S12 > S10 > L20 > S15 > > L10 > L60 > L100 > L80 > L0.

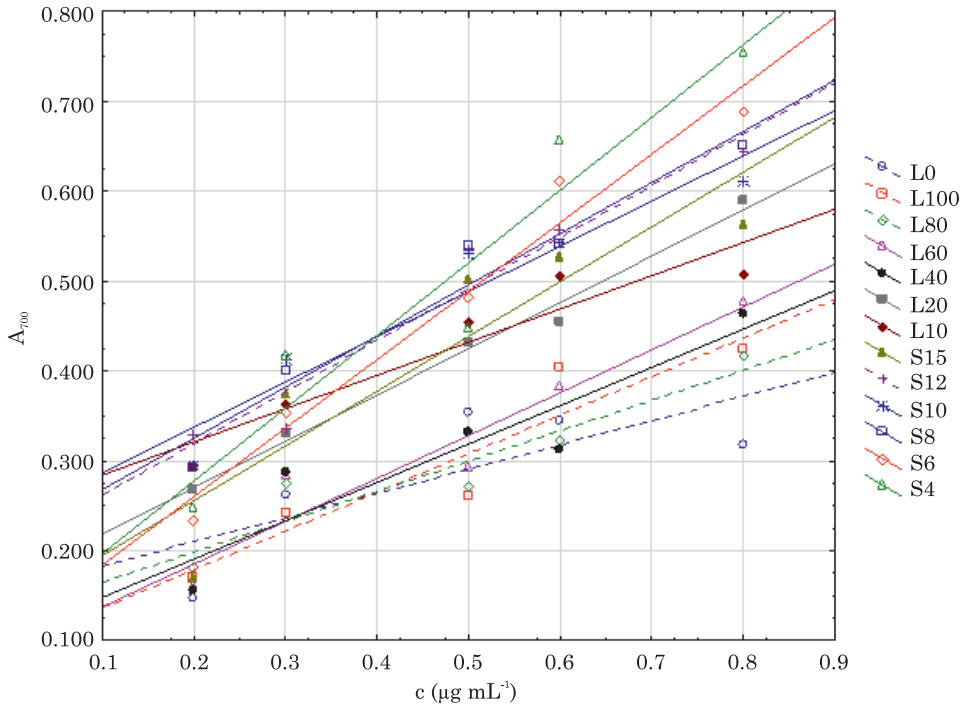


Fig. 4. Iron reducing activity of infusions with *Humulus lupulus*

The ability to inhibit AChE and BChE was demonstrated for all extracts tested, and it was expressed as an eserine equivalent (Figure 5).

Regarding the BChE inhibition, the samples containing hop leaves showed higher activity, in the decreasing order of L20 > L40 > L60 > L10 > > L80 > L100 > S4 > S15 > S6 > S10 > S8 > L0. Higher inhibitory activity was shown towards AChE, with the highest value in samples containing hop cones in the range from 19.29 in S6 to 21.09 eserine µM g^{-1} dw in S4, and in samples containing hop leaves from 17.22 in L10 to 18.87 eserine µM g^{-1} dw in L20.

The sensory evaluation of teas containing hop leaves and cones included the evaluation of such characteristics as: color, taste, smell and general desirability (Figure 6).

Straw color was the dominant color for most of the samples of the teas containing hop leaves of the Magnum cultivar. Among all the samples, the green color was the least noticeable, as it ranged from 2.22 to 3.16. The samples were characterized by varied clarity, the highest for L100 sample, with an average score of 4.47, and the lowest for L40 sample (1.83). Teas containing hop leaves were characterized by different types of taste, and none of the taste distinguishing features was dominant, except for bitter taste in L100 sample, where the value was 4.57. It was shown that sweet

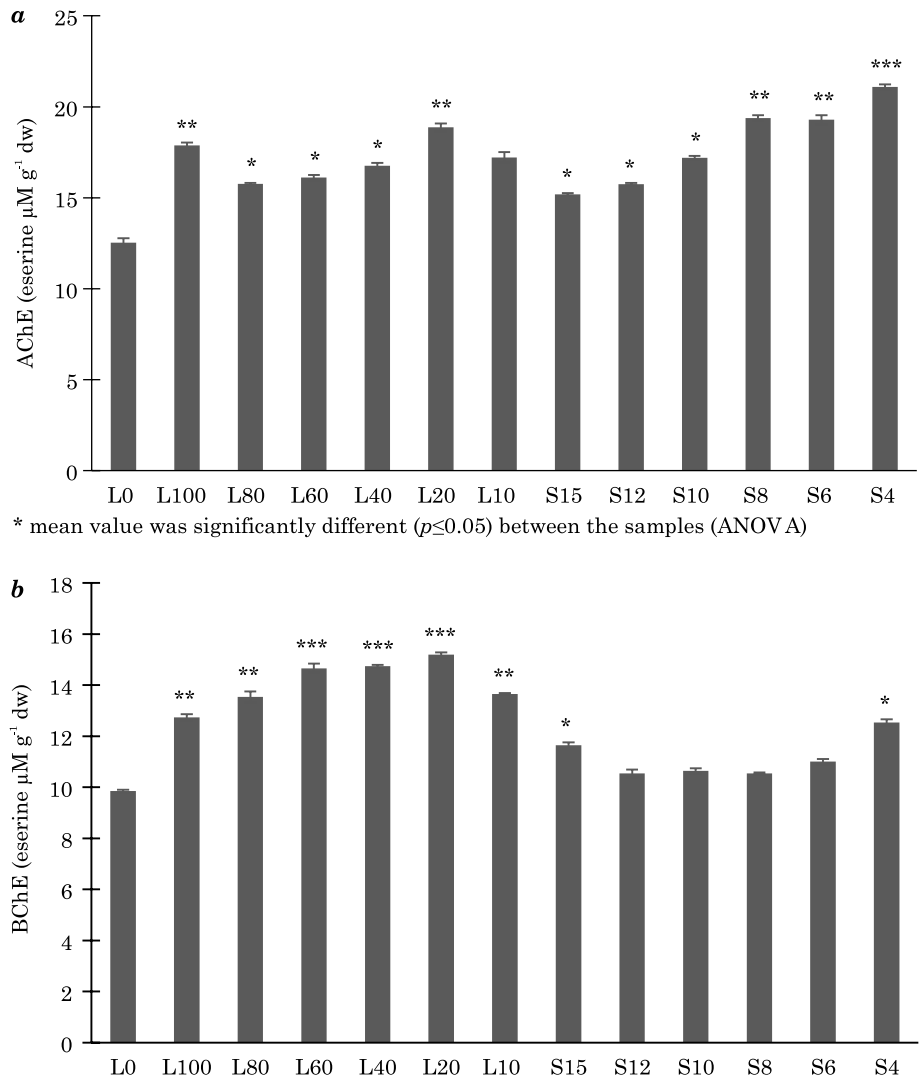


Fig. 5. Activity of extracts of *Humulus lupulus* hops as acetylcholinesterase (*a*) and butyrylcholinesterase (*b*) inhibitors

taste was determined within the range from 1.90 for sample L0 to 3.32 for sample L80 on a 10 point scale. With the exception of L100 sample, the tested teas were found to be little tangy and the scores for the severity of tangy flavor ranged from 1.89 to 3.45. Foreign taste was almost impalpable, except for the L100 sample, where it was scored an average of 2.16 on the 10-point scale. In the profile assessment of smell, no distinguishing smells were found. The most intense smell obtained from the tested samples was the sweet smell, ranging from 1.95 in sample L60 to 4.02 in sample L20.

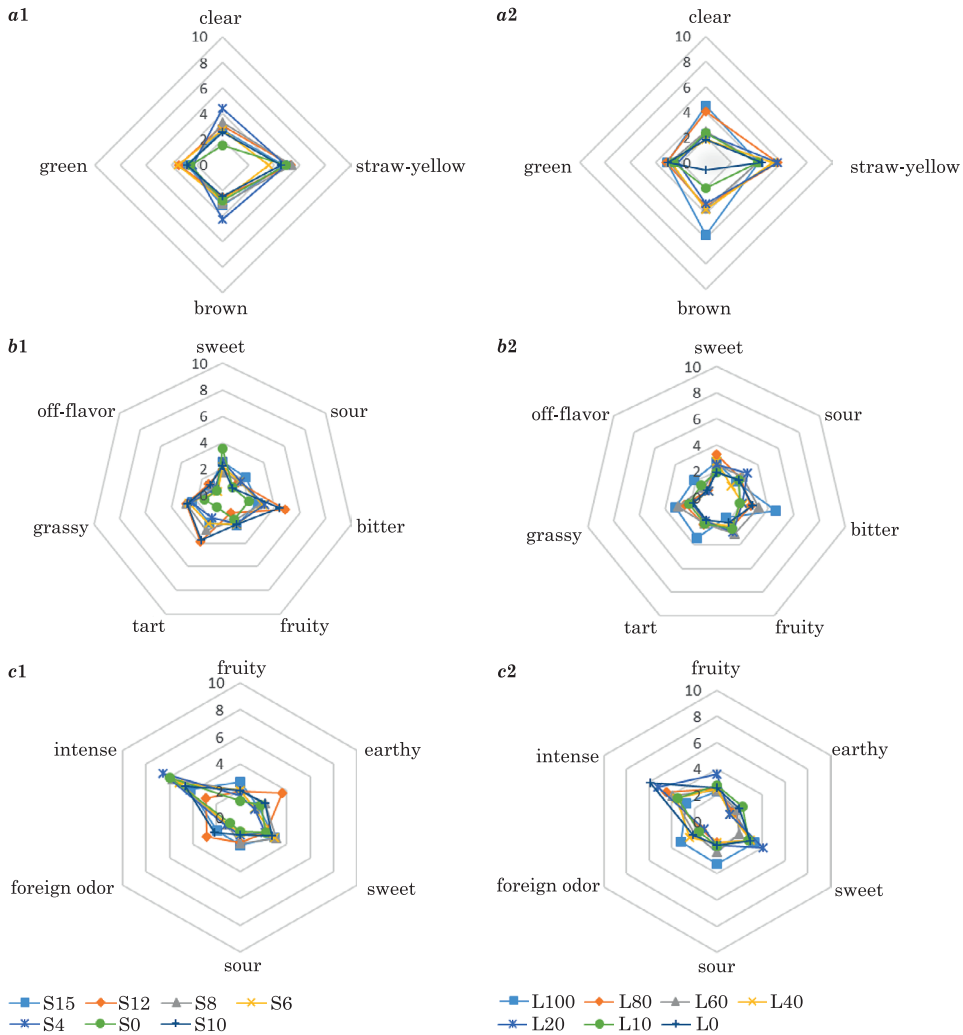
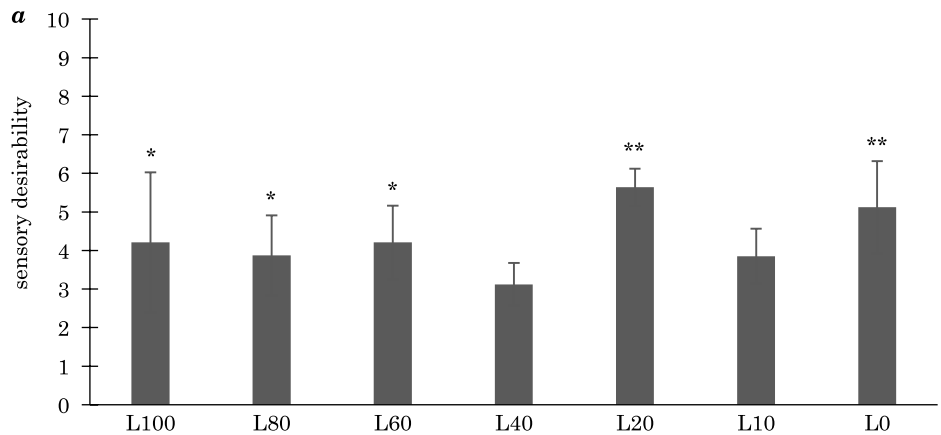


Fig. 6. Sensory profiles of dietary infusions with *Humulus lupulus* cones: *a*1 – color, *b*1 – taste. *c*1 – aroma, and *Humulus lupulus* leaves: *a*2 – color, *b*2 – taste, *c*2 – aroma

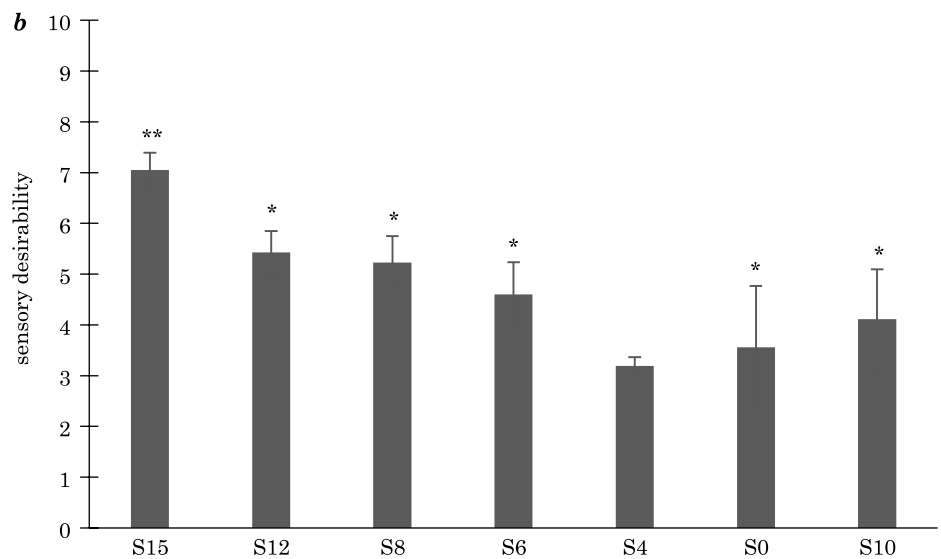
Almost all tea samples containing hop cones were assessed very similarly in terms of color differences towards straw color. Sample S4 was characterized by more intense brown color and was clearer, with the value for this feature scored at 4.39, compared with the scores between 1.52 to 3.31 assigned to the other samples. Individual samples were evaluated differently in terms of taste, but generally low intensity of this trait was observed. The bitter taste ranged from 2.03 to 3.24 in most of the samples, except for S10, which scored 4.4, and S12, which scored 4.87 on the scale up to 10 points. The smell of tea samples containing hop cones was assessed as varying in intensity from 2.93 in sample S12 to 6.55 in sample S4.

Sample L20, with an average value of 5.64, was evaluated the highest in terms of overall desirability, followed by the blank sample L0 assigned the value of 5.12. Samples L60, L80 and L10 were evaluated lower in terms of desirability, but on a similar level, with scores between 4.21 and 3.85, successively. The lowest score (2.73) was given to L100 sample.

In terms of overall desirability, the highest scores were given to S15 at 7.05 on a 10 point scale, followed by S12 with the score of 5.43. S4 sample was scored the lowest at 3.19 (Figure 7).



* mean value was significantly different ($p \leq 0.05$) between the samples (ANOV A)



* mean value was significantly different ($p \leq 0.05$) between the samples (ANOV A)

Fig. 7. Sensory desirability of dietary infusions made from: *a* – cones of *Humulus lupulus*, *b* – leaves of *Humulus lupulus*

DISCUSSION

Polyphenols are the compounds which have the ability to bind transition metal ions (Lin et al. 2013, Kobus-Cisowska et al 2019*b*). The mechanism of metal chelating by polyphenols consists of the formation of complexes between electron-donor molecules and metal ions with an unfixed valence coating. A potential site of metal chelating in the flavon-3-ol molecule is the catechol group of the B ring or the residue of gallic acid. The reaction mechanism begins with the detachment of the hydrogen atom by oxidation of the polyphenol molecule, then a phenoxyl radical is formed which makes a complex with it in the presence of a metal ion (Yuan et al. 2015). In previous studies, a significant amount of polyphenols was identified in hops (Kobus-Cisowska et al. 2019). In this study, however, it was shown that the polyphenols contained in hops are also compounds that can give off an electron or a hydrogen atom and thus have reducing properties (Figure 3). One study (Ürgeová, Polívka 2009) showed that the polyphenol content in extracts from leaves of Czech hop cultivars ranged from 0.14 mg g^{-1} d.m. to 14.34 mg g^{-1} d.m., depending on a cultivar and harvesting period. Although the analysis was performed using the Singelton method, it is a modified Folin-Ciocalteau assay of total phenolic substances that also uses gallic acid as a reference standard, and therefore the results are comparable to the ones reported in this paper. The study conducted by Jamroz et al. (2006), where the content of phenolic compounds in cones and pellets of the Magnum hop cultivar was analyzed, showed that extracts from this raw material contained on average about 45 mg of gallic acid g^{-1} of d.m., which seems to correspond well with the results obtained in our study, considering the fact that the content of hop cones in the prepared teas did not exceed 12%. According to Wojdyło et al. (2007), ethanol extracts from hop cones possess an antioxidant activity at the level of 83.2 uM Trolox 100 g^{-1} d.m., i.e. lower per g^{-1} than extracts containing hop leaves. However, ethanol was used in their study as a solvent, which could have led to differences between the cited and current results. Nevertheless, these values may indicate the expected properties of the analyzed teas, which are important in the prevention and treatment of neurodegenerative diseases. The key information on the causes of elevated oxidative stress in the nervous tissue of patients affected by these diseases was provided by a thorough analysis of protein deposits present in the nervous tissue of patients. In patients affected by Alzheimer's disease, elevated concentrations of copper, iron and zinc ions have been observed in pathologically altered areas of the brain (Bagheri et al. 2018). Increased concentrations of iron ions in the compact part of the substantia nigra were also found in Parkinson's disease patients (Guo et al. 2018). Copper and iron ions can quickly change the degree of oxidation. These processes are desirable for the action of prosthetic groups in numerous enzymes, but outside of enzymes they can cause the production

of reactive hydroxyl radicals by the Fenton reaction. The existence of two coupled reactions, in which metal ions are oxidized and then reduced (regenerated), allows the Fenton reaction to occur even in the presence of very low concentrations of metal ions (Mor, Ischiropoulos 2018, Zhao 2019). Simultaneous increase in the concentration of metal ions and dopamine in the substantia nigra's neurons, characteristic for neurodegenerative diseases, leads to intensive formation of complexes of this neurotransmitter and metal ions. Dopamine bound to a transition metal ion has prooxidative properties. Therefore, compounds that have the ability to chelate such metals, such as ones found in hop cones or leaves, are becoming more important (Hare, Double 2016). An elevated level of oxidative stress caused by the binding of metal ions by abnormally corrugated peroxide dismutase was also found in the course of lateral atrophic sclerosis (Pollari et al. 2016). In this respect, the ability to inactivate radicals is also gaining importance, which in the case of this study was documented for DPPH radicals (Figure 2). There is ongoing research into the use of extracts from plant materials helpful in inhibiting AChE and BChE in Alzheimer's disease (Bilska et al. 2019). In this respect, antioxidant capacity, i.e. reducing, chelating and antiradical activity, is indicated in particular. An example is *Humulus lupulus* extract, which is reported to have a high activity, which depends on a concentration of the extract and a cultivar of origin (Kobus-Cisowska 2019). The study explains one of the mechanisms of action of the infusions containing hop leaves and cones fractions, i.e., inhibition of cholinesterases. These raw plant materials act mainly via two mechanisms: inactivation of radicals, chelating and reduction of transition metals, which may affect the functions of the central nervous system. However, this study indicates that the activity is dependent on the anatomical part of hops and the proportion of other ingredients of teas. Previous experiments have shown that mint has cholinesterase-inhibiting properties. As shown by Hanafy et al. (2017) mint teas show a moderate AChE inhibitory activity and, similarly to the samples analyzed in our experiment, the BChE inhibitory activity of mint teas was found to be lower. Higher activity was found with respect to AChE, especially in samples containing hop cones: S4, S8 and S6. To our knowledge, there is currently no research conducted on yellow tea and mulberry leaves as cholinesterase inhibitors, but being aware that naturally occurring compounds from plants are considered to be a potential source of inhibitors, we can presume that they can act synergistically in such dietary infusions (Murray et al. 2013). Therefore, the use of hop cone tea in a diet of patients treated for neurodegenerative diseases may affect the course and development of this disease.

Palatability has the greatest impact on the consumer's motivation to choose a particular food product (Johnson, Wardle 2014), hence acceptable and desirable sensory properties are crucial in health-promoting food design. Common hops are highly bitter and have a distinct taste because of their alpha-acid content, which increases bitterness due to thermal isomerization

(Rattberg et al. 2018). Although the bitter taste of hops is desirable in breweries, it is aversive in many products and new bitterness masking methods are being sought (Mennella et al. 2013). In the study, products with pro-health properties and desired taste were obtained by using hop leaves and low concentrations of hop cones. The infusions thus obtained were characterized by a less intense and well-balanced taste.

CONCLUSIONS

Common hops are a raw plant material with specific health and sensory properties. In the food industry, they can be successfully used not only in breweries but also as a functionally important ingredient in teas. The use of hop cones and leaves in combination with leaves of such plants as white mulberry, mint and yellow tea makes it possible to obtain sensory-acceptable teas with characteristic sensory properties. Depending on a selected proportions of ingredients, prepared teas differ in color, smell, taste and general desirability. Sensory tests showed that the most desirable sample is a tea containing 15% of hop cones and 29.3% of white mulberry, yellow tea and mint leaves. The teas prepared with added hop leaves and cones contain polyphenols and have antiradical activity. They exhibit cholinesterase inhibiting properties, and the ability to chelate and reduce iron. Among the tested samples, the tea containing 12% of hop cones was the richest in polyphenols, whereas tea containing 80% of hop leaves showed the highest antioxidant activity.

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