Antioxidant characteristics of tea-herbal compositions

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Abstract

Keywords:

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Introduction. The aim of the study was to determine the antioxidant capacity of herbal infusions and evaluate the possibility of using them to create herbal tea compositions.

Materials and methods. Antioxidant capacity of tea-herbal compositions was determined by redoxmetry and pH-metry; sensory indicators were evaluated by expert method; results of mathematical and statistical processing were assessed by the method of linear Pearson correlation.

Results and discussion. The pH for water infusions from raw materials has a value of 2.35 for *Hibiscus sabdariffa* and 6.55 for *Calamintha nepeta*. The minimum theoretical value of RP ($E_{h_{min}}$) for plant water infusions was obtained, which has a value from 267.0 mV for *Calamintha nepeta* to 519.0 mV for *Hibiscus sabdariffa*. The actual measured RP of infusions ($E_{h_{act}}$) was established as 37.0 mV for *Daucus carota* and 203.0 mV for *Hibiscus sabdariffa*. Water infusions from vegetable raw materials have the value of regenerative capacity (recovery energy, RE_{inf}) in the range from RE_{inf} 150.8 mV for *Vitis vinifera*) to RE_{inf} 316.0 mV for *Hibiscus sabdariffa*. For the restaurant business in the manufacture of beverages are promising water infusions of *Hibiscus sabdariffa* and *Citrus limonum*, which received increased antioxidant characteristics RE_{inf} 316.0 mV and 298.0 mV, respectively, and positive sensory evaluation. It is proved that the energy of reduction/oxidation of vegetable raw materials (RE_{plant}) relative to the solvent – prepared water is in the range of values from 45.8 mV for *Vitis vinifera* to 211.0 mV for *Hibiscus sabdariffa*. Based on mathematical and statistical analysis, it was found that physicochemical parameters in the range of values with very high correlation (r 0.9–1.0) includes the following indicators: pH, $E_{h_{min}}$, RE_{inf} , RE_{plant} . Rational composition of tea-herbal composition was found: *Hibiscus sabdariffa*, 30 %; *Matricaria chamomilla*, 20 %; *Ilex paraguariensis*, 10 %; *Rosae fructus*, 10 %; *Mentha piperita*, 10 %; *Citrus sinensis*, 8 %; *Citrus limonum*, 7 %; *Calendulae flores*, 5 %.

Conclusion. For the technology of the restaurant industry, the use of tea-herbal compositions from plant materials *Hibiscus sabdariffa*, *Matricaria chamomilla*, *Ilex paraguariensis*, *Rosae fructus*, *Mentha piperita*, *Citrus sinensis*, *Citrus limonum*, *Calendulae flores*, which have increased antioxidant characteristics, is proposed.

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Introduction

Characteristics of tea

The interest of consumers in tea (*Camellia sinensis*) (Spizzirri et al., 2019) is explained by the fact that tea has pleasant characteristics of taste, aroma, color (Banerjee (Roy) et al. 2016; Xu et al., 2018; Zeng et al., 2017). The aroma molecules are formed mainly from precursor groups: carotenoids, fatty acids, glycosides, amino acids/sugars, volatiles ketones and alkenes (Chen et al., 2019; Feng et al., 2019; Guo et al., 2019; Li et al., 2019; Qi et al., 2018; Zhu et al., 2016). Tea aroma concentration determined by the following sequence: black > white > oolong > dark > yellow > green. Black tea has the highest volatile concentration of 710 µg/g, while green tea has the lowest concentration of 20 µg/g (Feng et al., 2019). Tea has a tonic effect (Długaszek et al., 2020) – to maintain the health (Hayat et al., 2015; Spizzirri et al., 2019; Vuong, 2014), normalizes metabolism, increases efficiency, eliminates fatigue (Długaszek, Kaszczuk, 2020), increases resistance to stress (Xia et al., 2020). If soft drinks lower the temperature only in the oral cavity, then tea has the ability to lower the temperature of the whole body by 1–2 °C.

Tea possesses significant antioxidative, anti-inflammatory, antimicrobial, anticarcinogenic, antihypertensive, anti-cancer, neuroprotective, cholesterol-lowering, and thermogenic properties (Bekhit et al., 2011; Hayat et al., 2015; Pérez-Burillo et al., 2018; Somasundaram et al., 2019; Spizzirri et al., 2019; Vuong, 2014; Xu et al., 2018).

In teas it has been found, according to some authors 143 (Guo et al., 2019), 168 (Feng et al., 2019) and 172 (Chen et al., 2019) bioactive compounds. These ones include catechins (Pérez-Burillo et al., 2018; Somasundaram et al., 2019), polyphenols with the properties of vitamin P (Hayat et al., 2015; Pérez-Burillo et al., 2018; Spizzirri et al., 2019; Vuong, 2014), and accumulates such vitamins as ascorbic acid, thiamine, riboflavin, nicotinic, pantothenic and folic acids, carotenoids (Aboagye et al., 2021).

The tea contains antioxidants, in particular catechin, which protects the body from peroxidation – the process of self-oxidation of intracellular and tissue fat, the products of which not only reduce the function of the cell, but can also lead to its death. Tea catechins almost completely eliminate the harmful effects on the body during radioactive fallout. They have the ability to adsorb an isotope and remove it from the body before it can reach the bone marrow. Catechins also «monitor» the level of polyunsaturated fatty acids in the body, normalize cholesterol metabolism (Chen et al., 2020).

The tea leaves contain alkaloids – caffeine (Pérez-Burillo et al., 2018), theophylline, theobromine. The peculiarity of tea alkaloids is that they show their biological effect in combination with catechins and other constituents of tea. As a result, the tonic effect of tea does not cause such a sharp stimulating effect as coffee, in which the alkaloid caffeine is present in its pure form (Chen et al., 2020).

Tea is a rich source of minerals. About 20 amino acids are found in tea, and in their composition – all irreplaceable, it also contains carbohydrates, pectin substances, organic acids, resins, and essential oils (Theuma and Attard, 2020).

Characteristics of herbal tea

Herbal tea determined by the herbal components that make up the complex tea mixture. Herbal tea a mixture of black or green tea with medicinal or aromatic herbs (Coppock and Dziwenka, 2021). Tea drinks are used as substitutes for black tea in the case when there is an intolerance to the components of the tea leaf extract tannins and alkaloids such as caffeine, and theobromine because herbal tea unlike the tea, do not contain caffeine. In China, 759 species of plants are used as herbal tea (Fu et al., 2018).

Herbal tea is a versatile drink that has a healing effect and can also be used as a preventive or therapeutic agent (Ağagündüz, 2020; Chen et al., 2019; Halim et al., 2020). Herbal tea contains a much larger amount of irreplaceable biologically active substances; constantly maintain the chemical balance of the body (Liu et al., 2020). Herbal teas increase antioxidant status (Bekhit et al., 2011; Debnath-Canning et al., 2020; Ertas, Yener, 2020; Spizzirri et al., 2019), oxidative status (Ağagündüz, 2020; Abdullah and Mazlan, 2020), anticancer activity (Morré and Morré, 2006), and has radio-protective effect (Ansari et al., 2021). Although many people drink herbal teas for pleasure, elderly people that live in rural areas often use herbal teas as affordable, accessible, and effective alternatives to medicine (Joubert et al., 2008).

Depending on the composition of raw materials and physiological effects, tea drinks are divided into groups: (a) multivitamin; regulating metabolism in the body; (b) tonic; soothing; anti-inflammatory; universal, and children's (Sviridonov et al., 2003). Most often, complex herbal compositions are used and one or more of the following components are added to the main infusion based on black (less often green) tea:

- Leaves: black currant (Liu et al., 2014), blueberry (Debnath-Canning et al., 2020), lemongrass (Aboagye et al., 2021), mint (Chan et al., 2010; Cohen et al., 2020; Somasundaram et al., 2019), nettle (Shonte et al., 2020), oregano (Chan et al., 2010), raspberry (Han et al., 2012), sea buckthorn (Ma et al., 2019), St. John's wort (Dell'Aica et al., 2007), rooibos, honeybush (Małjurek et al., 2021), and mate (Mesquita et al., 2021);
- Flowers: hibiscus (Bekhit et al., 2011; Frész et al., 2014), cloves (Somasundaram et al., 2019), linden (Pavlović et al., 2020), calendula (Nicolaus et al., 2017), rose hip (Frész et al., 2014), and chamomile (Chaves et al., 2020);
- Fruits: apple (Bobrowska-Grzesik and Jakóbik-Kolon, 2008), apricot (Saeed et al., 2021), berberis (Atefi et al., 2021; Salehi et al., 2019), bilberry (Bobrowska-Grzesik and Jakóbik-Kolon, 2008; Šavikin et al., 2014), black currant (Šavikin et al., 2014), chokeberry (Šavikin et al., 2014), grapes (Ansari et al., 2021; Bekhit et al., 2011; Morré, Morré, 2006), hawthorn (Dragan et al., 2012), lemon (He et al., 2018; Spizzirri et al., 2019), peach (Spizzirri et al., 2019), raspberries (Falcó et al., 2019), strawberries (Falcó et al., 2019), viburnum (Podsędek et al., 2020), and rose hip (Piljac-Žegarac et al., 2010);
- Stalks: cloudbberries (Puupponen-Pimiä et al., 2016), cherries (Zhang et al., 2016), and sweet cherries (Faenza et al., 2020);
- seeds: dill (Cohen et al., 2020), caraway (Cohen et al., 2020), and coriander (Beyzi et al., 2017);
- Roots: ginger (Somasundaram et al., 2019), burdock (Maghsoumi-Norouzabad et al., 2019), and licorice (Jeon et al., 2007).

Perspective directions of tea-herbal compositions

To improve tea drinks assortment, the following ideas and suggestions are proposed:

- Use of new breeding varieties of tea plants and areas of its growth (Xu et al., 2021);
- Development of new technological solutions for tea plant processing (Dubey et al., 2020; Zohurul et al., 2020);
- Addition of leaves of various medicinal plants to tea (Baek et al., 2018; Vidović et al., 2013);
- Addition of various flavors to tea.

Relevance of the research direction

The relevance of this topic is that the tea market is overflowing with a variety of tea drinks. Therefore, there is a need to create a qualitatively new tea-herbal composition for functional purposes.

The aim of the research is to determine the antioxidant capacity of plant raw materials infusions and evaluate their prospects for the creation of tea-herbal compositions.

To achieve the desired results, it was necessary:

(a) Confirm the feasibility of using plant materials in the creation of tea and herbal compositions.

(b) Determine the antioxidant capacity of plant materials used for the preparation of infusions.

(c) Perform mathematical and statistical analysis of antioxidant capacity of plant raw materials used in the tea-herbal compositions and to establish the internal correlation.

(d) Identify the richest sources of natural antioxidants from plant raw materials in the technology of tea-herbal compositions.

(e) Study the changes in vegetable materials in the process of blending tea and herbal compositions.

The introduction of various medicinal plants into tea makes it possible to increase the physiological activity of the original drink (Bag et al., 2022; Peng et al., 2021; Shabab et al., 2021). Since medicinal plants contain various vitamins and vitamin-like substances (Khan et al., 2021; Pohl et al., 2016), phenolic compounds (Albergaria et al., 2020), ash elements, organic acids, their introduction into tea could significantly increase the physiological value of this drink.

Materials and methods

Materials

23 samples of vegetable raw materials were used in the present study: *Vitis vinifera*; *Calamintha nepeta*; *Monarda didyma*; *Satureja hortensis*; *Agastache foeniculum*; *Rosae fructus*; *Ruta graveolens*; *Elsholtzia stauntonii* Benth; *Perilla frutescens*; *Artemisia abrotanum*; *Melissae herba*; *Aspalathus linearis*; *Tiliae flos*; *Mentha piperita*; *Matricaria chamomilla*; *Herba Hyperici*; *Inonotus obliquus*; *Daucus carota*; *Ilex paraguariensis*; *Calendulae flores*; *Citrus sinensis*; *Citrus limonum*; *Hibiscus sabdariffa*. Prepared water was used as a control sample and extractant.

Methods of obtaining water infusion

Drying of vegetable raw materials was carried out to constant humidity of 6–8 %. Collected and inspected raw materials were laid out on clean white paper, each type separately. Vegetable raw materials were ground with scissors to a size of 3x3 mm, samples weighing 4 g were placed in 100 ml of prepared hot water. The infusions were filtered and studies were performed to determine the indicators of active acidity, which was measured on a pH meter in the mode of pH measurement with a combined glass electrode. The RP was measured in the potential measurement mode with a combined redoxmetric platinum electrode (Kuzmin et al., 2020).

Methods for determining active acidity and *RP*

The active acidity index was measured on a pH-meter «pH-150M» with a combined glass electrode «ESC 10601/4». *RP* was measured on the pH-meter «pH-150M», in the mode of measuring the potential, with a redoxmetric platinum electrode «ERP-105».

To assess the antioxidant properties of aqueous infusions of plant raw materials a method based on the difference of *RP* in inactivated inorganic solutions and complex biochemical media was used (Priluckij, 1997). The main criteria of this method were its clarity, simplicity, specificity, reproducibility of results and efficiency. A number of researchers also emphasize that method allows to determine the total antioxidant activity of liquid products, including in total in a complex mixture, and multifunctional antioxidants (Kuzmin et al., 2020).

Formula (1) holds for inactivated inorganic solutions in equilibrium. This formula links the active acidity of the pH and the *RP* (Priluckij, 1997):

$$Eh_{min}=660-60 \cdot \text{pH}, \text{ mV} \quad (1)$$

where Eh_{min} is the minimum theoretically expected value of the *RP*;

pH is active acidity of the test solution.

Acquired meanings of Eh_{min} were compared with the actual measurements of Eh_{act} of infusions. The shift of the *RP* to the side of the recovered meanings – recovery energy (RE_{inf}) was determined by the formula (Priluckij, 1997):

$$RE_{inf}=Eh_{min}-Eh_{act}, \text{ mV} \quad (2)$$

where RE_{inf} is the shift of the *RP* to the side of recovered meanings;

Eh_{act} is actual measured of the *RP*.

The energy of reduction/oxidation of vegetable raw materials (RE_{plant}) is determined by the difference between the *RP* of infusions of vegetable raw materials (RE_{inf}) and solvent (RE_{sol}) (control is prepared water) (Kuzmin et al., 2020):

$$RE_{plant}=RE_{inf}-RE_{sol}, \text{ mV} \quad (3)$$

Based on the research results, an improved method for assessing the antioxidant capacity of herbal infusions for creating tea-herbal compositions has been developed.

Expert method of sensory evaluation

The expert method of values quality indexes determination is based on committing the thought of the highly skilled and experienced specialists-experts (Kuzmin et al., 2020).

Mathematical and statistical methods

Pearson correlation coefficient measures the strength of the linear association between variables. Each variable should be continuous, random sample and approximately normally distributed. There are many rules of thumb on how to interpret a correlation coefficient, but all of them are domain specific. For example, here is correlation coefficient (Table 1) interpretation for behavioral sciences offered by Hinkle et al., 2003.

Table 1

Correlation coefficient interpretation

Absolute value of coefficient (r)	Strength of correlation
0.90–1.00	Very high
0.70–0.90	High
0.50–0.70	Moderate
0.30–0.50	Low
0.00–0.30	Little, if any

The correlation coefficient can take a range of values from +1 to -1. Positive correlation coefficient means that if one variable gets bigger, the other variable also gets bigger, so they tend to move in the same direction. Negative correlation coefficient means that the variables tend to move in the opposite directions: If one variable increases, the other variable decreases, and vice-versa. When correlation coefficient is close to zero two variables have no linear relationship (Hinkle et al., 2003; Shendrik et al., 2019).

Results and discussions

Results of antioxidant capacity

Physicochemical studies, namely determination of the pH level and RP (Nicoli et al., 2004; Prévost, Brillet-Viel, 2014), were performed according to the method (Priluckij, 1997) and calculations given above (Kuzmin et al., 2020). As a result of extraction received infusions (Andreou et al., 2018), physicochemical indicators (Breiter et al., 2011) of which are presented in the Table 2. As a solvent used a prepared water: pH 8.00 units pH ; Eh_{min} 180.0 mV; Eh_{act} 75.0 mV; RE_{inf} 105.0 mV.

Figures 1-5 show graphically the change in the physicochemical indicators of the quality of extracts of raw materials on the extractant.

The pH for water infusions from raw materials (Figure 1) has a value of 2.35 units pH (*Hibiscus sabdariffa*) to 6.55 units pH (*Calamintha nepeta*).

The minimum theoretical value of RP (Eh_{min}) for plant water infusions (Priluckij, 1997) was obtained, which has a value from 267.0 mV (*Calamintha nepeta*) to 519.0 mV (*Hibiscus sabdariffa*) (Figure 2).

The actual measured RP of infusions (Eh_{act}) was established – from 37.0 mV (*Daucus carota*) to 203.0 mV (*Hibiscus sabdariffa*) (Figure 3).

Table 2

Quality indicators of extracts on extractant

Plant raw materials	pH , units pH	Eh_{min} , mV	Eh_{act} , mV	RE_{inf} , mV	RE_{plant} , mV
1. Extractant – prepared water	8.00	180.0	75.0	105.0	0.0
2. <i>Vitis vinifera</i>	6.47	271.8	121.0	150.8	45.8
3. <i>Calamintha nepeta</i>	6.55	267.0	94.0	173.0	68.0
4. <i>Monarda didyma</i>	6.39	276.6	102.0	174.6	69.6
5. <i>Satureja hortensis</i>	6.48	271.2	96.0	175.2	70.2
6. <i>Agastache foeniculum</i>	6.32	280.8	95.0	185.8	80.8
7. <i>Rosae fructus</i>	6.11	293.4	107.0	186.4	81.4
8. <i>Ruta graveolens</i>	6.07	295.8	108.0	187.8	82.8
9. <i>Elsholtzia stauntonii</i> Benth	6.48	271.2	80.0	191.2	86.2
10. <i>Perilla frutescens</i>	6.24	285.6	93.0	192.6	87.6
11. <i>Artemisia abrotanum</i>	6.23	286.2	89.0	197.2	92.2
12. <i>Melissae herba</i>	6.18	289.2	90.0	199.2	94.2
13. <i>Aspalathus linearis</i>	6.00	300.0	95.0	205.0	100.0
14. <i>Tiliae flos</i>	6.31	281.4	76.0	205.4	100.4
15. <i>Mentha piperita</i>	6.01	300.0	86.0	214.0	109.0
16. <i>Matricaria chamomilla</i>	5.58	325.2	105.0	220.2	115.2
17. <i>Herba Hyperici</i>	5.00	360.0	132.0	228.0	123.0
18. <i>Inonotus obliquus</i>	5.40	336.0	97.0	239.0	134.0
19. <i>Daucus carota</i>	6.39	276.6	37.0	239.6	134.6
20. <i>Ilex paraguariensis</i>	5.87	307.8	57.0	250.8	145.8
21. <i>Calendulae flores</i>	5.55	327.0	63.0	264.0	159.0
22. <i>Citrus sinensis</i>	5.18	349.2	54.0	295.2	190.2
23. <i>Citrus limonum</i>	4.85	369.0	71.0	298.0	193.0
24. <i>Hibiscus sabdariffa</i>	2.35	519.0	203.0	316.0	211.0
min	2.35	267.0	37.0	150.8	45.8
max	6.55	519.0	203.0	316.0	211.0

where: pH – active acidity of the test solution; Eh_{min} – the minimum theoretically expected value of the RP ; Eh_{act} – actual measured of the RP ; RE_{inf} – the shift of the RP to the side of recovered meanings; RE_{plant} – the energy of reduction/oxidation of vegetable raw materials

Water infusions from vegetable raw materials have the value of regenerative capacity (recovery energy – RE_{inf}) in the range from RE_{inf} – 150.8 mV (*Vitis vinifera*) to RE_{inf} – 316.0 mV (*Hibiscus sabdariffa*).

For the restaurant business in the manufacture of beverages are promising water infusions of *Hibiscus sabdariffa* and *Citrus limonum*, which received increased antioxidant characteristics RE_{inf} – 316.0 mV and RE_{inf} – 298.0 mV, respectively (Figure 4), and positive sensory evaluation.

Figure 1. Hydrogen index (pH) of infusions of the investigated raw material:

1 – Extractant; 2 – *Vitis vinifera*; 3 – *Calamintha nepeta*; 4 – *Monarda didyma*;
 5 – *Satureja hortensis*; 6 – *Agastache foeniculum*; 7 – *Rosae fructus*; 8 – *Ruta graveolens*;
 9 – *Elsholtzia stauntonii* Benth; 10 – *Perilla frutescens*; 11 – *Artemisia abrotanum*;
 12 – *Melissae herba*; 13 – *Aspalathus linearis*; 14 – *Tiliae flos*; 15 – *Mentha piperita*;
 16 – *Matricaria chamomilla*; 17 – *Herba Hyperici*; 18 – *Inonotus obliquus*; 19 – *Daucus carota*;
 20 – *Ilex paraguariensis*; 21 – *Calendulae flores*; 22 – *Citrus sinensis*; 23 – *Citrus limonum*;
 24 – *Hibiscus sabdariffa*

Figure 2. Minimum theoretical value of RP (Eh_{min}) of infusions of the investigated raw material:

1 – Extractant; 2 – *Vitis vinifera*; 3 – *Calamintha nepeta*; 4 – *Monarda didyma*;
 5 – *Satureja hortensis*; 6 – *Agastache foeniculum*; 7 – *Rosae fructus*; 8 – *Ruta graveolens*;
 9 – *Elsholtzia stauntonii* Benth; 10 – *Perilla frutescens*; 11 – *Artemisia abrotanum*;
 12 – *Melissae herba*; 13 – *Aspalathus linearis*; 14 – *Tiliae flos*; 15 – *Mentha piperita*;
 16 – *Matricaria chamomilla*; 17 – *Herba Hyperici*; 18 – *Inonotus obliquus*; 19 – *Daucus carota*;
 20 – *Ilex paraguariensis*; 21 – *Calendulae flores*; 22 – *Citrus sinensis*; 23 – *Citrus limonum*;
 24 – *Hibiscus sabdariffa*

Figure 3. Actual measured RP of infusions (E_{hact}) of the investigated raw material:

1 – Extractant; 2 – *Vitis vinifera*; 3 – *Calamintha nepeta*; 4 – *Monarda didyma*;
 5 – *Satureja hortensis*; 6 – *Agastache foeniculum*; 7 – *Rosae fructus*; 8 – *Ruta graveolens*;
 9 – *Elsholtzia stauntonii* Benth; 10 – *Perilla frutescens*; 11 – *Artemisia abrotanum*;
 12 – *Melissae herba*; 13 – *Aspalathus linearis*; 14 – *Tiliae flos*; 15 – *Mentha piperita*;
 16 – *Matricaria chamomilla*; 17 – *Herba Hyperici*; 18 – *Inonotus obliquus*; 19 – *Daucus carota*;
 20 – *Ilex paraguariensis*; 21 – *Calendulae flores*; 22 – *Citrus sinensis*; 23 – *Citrus limonum*;
 24 – *Hibiscus sabdariffa*

Figure 4. Recovery energy (RE_{inf}) of infusions of the investigated raw material:

1 – Extractant; 2 – *Vitis vinifera*; 3 – *Calamintha nepeta*; 4 – *Monarda didyma*;
 5 – *Satureja hortensis*; 6 – *Agastache foeniculum*; 7 – *Rosae fructus*; 8 – *Ruta graveolens*;
 9 – *Elsholtzia stauntonii* Benth; 10 – *Perilla frutescens*; 11 – *Artemisia abrotanum*;
 12 – *Melissae herba*; 13 – *Aspalathus linearis*; 14 – *Tiliae flos*; 15 – *Mentha piperita*;
 16 – *Matricaria chamomilla*; 17 – *Herba Hyperici*; 18 – *Inonotus obliquus*; 19 – *Daucus carota*;
 20 – *Ilex paraguariensis*; 21 – *Calendulae flores*; 22 – *Citrus sinensis*; 23 – *Citrus limonum*;
 24 – *Hibiscus sabdariffa*

It is proved that the energy of reduction/oxidation of vegetable raw materials (RE_{plant})

relative to the solvent – prepared water is in the range of values from 45.8 mV (*Vitis vinifera*) to 211.0 mV (*Hibiscus sabdariffa*) (Figure 5). It was found that water infusions, depending on the activity of plant raw materials have a reducing capacity (over 0 mV) – 100% of samples.

Figure 5. Energy of reduction/oxidation of vegetable raw materials (RE_{plant}):

1 – Extractant; 2 – *Vitis vinifera*; 3 – *Calamintha nepeta*; 4 – *Monarda didyma*; 5 – *Satureja hortensis*; 6 – *Agastache foeniculum*; 7 – *Rosae fructus*; 8 – *Ruta graveolens*; 9 – *Elsholtzia stauntonii* Benth; 10 – *Perilla frutescens*; 11 – *Artemisia abrotanum*; 12 – *Melissae herba*; 13 – *Aspalathus linearis*; 14 – *Tiliae flos*; 15 – *Mentha piperita*; 16 – *Matricaria chamomilla*; 17 – *Herba Hyperici*; 18 – *Inonotus obliquus*; 19 – *Daucus carota*; 20 – *Ilex paraguariensis*; 21 – *Calendulae flores*; 22 – *Citrus sinensis*; 23 – *Citrus limonum*; 24 – *Hibiscus sabdariffa*

Determination of Pearson's linear correlation

According to the physicochemical and sensory evaluation, mathematical and statistical analysis (Hinkle et al., 2003; Shendrik et al., 2019) was performed in the Pearson correlation matrix (Table 3).

Table 3

Marked correlations (r) are significant at $p < 0,05$; $N = 24$

	pH	Eh_{min}	Eh_{act}	RE_{inf}	RE_{plant}
pH		-1.00	-0.58	-0.85	-0.85
Eh_{min}	-1.00		0.58	0.85	0.85
Eh_{act}	-0.58	0.58		0.06	0.06
RE_{inf}	-0.85	0.85	0.06		1.00
RE_{plant}	-0.85	0.85	0.06	1.00	

where: pH – active acidity of the test solution; Eh_{min} – the minimum theoretically expected value of the RP ; Eh_{act} – actual measured of the RP ; RE_{inf} – the shift of the RP to the side of recovered meanings; RE_{plant} – the energy of reduction/oxidation of vegetable raw materials

According to the obtained matrix 5×5 , it was found that of the 5 indicators (pH , Eh_{min} , Eh_{act} , RE_{inf} , RE_{plant}) in the range of values with very high correlation (r 0.9-1.0) includes the following indicators: pH , Eh_{min} , RE_{inf} , RE_{plant} .

Figure 6 shows the graphical dependence of pH on Eh_{min} . It was found that the pH is in the range of 2.35–8.00, and Eh_{min} – 519.0–180.0 mV. According to the obtained equation, at a pH value of 6.00 Eh_{min} is 300 mV. When the pH value changes by 1 (pH 5.00), the Eh_{min} increases by 60 mV (Eh_{min} 360 mV). That is, the relationship between Eh_{min} and pH is very high, because $r=-1$, because it is inversely correlated, which leads to an increase in pH to a decrease in the level of Eh_{min} .

Figure 6. Dependence of pH level on Eh_{min}

Figures 7-11 show the graphical dependence of the pH level, Eh_{min} , RE_{inf} , RE_{plant} .

It was found that RE_{inf} is in the range from 105 to 316 mV, and the pH is 8.00–2.35. At the value of RE_{inf} 205 mV, the pH level is 6.0. If you reduce the pH to by one to 5.0 then the value of RE_{inf} will be 228 mV, i.e. RE_{inf} will increase by 23 mV. This is due to the fact that there is a high interdependence between the variables RE_{inf} and pH ($r=-0.85$). As the pH value increases, the RE_{inf} index decreases (Figure 7).

It was found that RE_{plant} is in the range from 0.0 to 211.0 mV, and the pH is 8.00–2.35. When the value of RE_{plant} 100.0 mV, the pH level is 6.0. If you reduce the pH by one to 5.0, the value of RE_{plant} will be 123.0 mV. Decreasing the pH per unit from 6.0 to 5.0 leads to a decrease in RE_{plant} by 23 mV. This is due to the fact that there is a high interdependence between the variables RE_{plant} and pH ($r=-0.85$). As the pH value increases, the RE decreases (Figure 8).

Figure 11 shows the graphical dependence of RE_{plant} on RE_{inf} . It was found that the RE_{plant} is in the range of 0.0 to 211.0 mV, and RE_{inf} – 105 to 316 mV. According to the obtained equation, at a RE_{plant} value of 100 mV RE_{inf} is 205 mV. When the RE_{plant} value changes by 1 (RE_{plant} 101 mV), the RE_{inf} decreases by 105 mV (RE_{inf} 206 mV). That is, the relationship between RE_{plant} and RE_{inf} is very high, because $r=1$, because it is directly correlated, which leads to an increase in RE_{plant} to a increase in the level of RE_{inf} .

Scatterplot: pH vs. RE_{inf} (Casewise MD deletion)

$$RE_{inf} = 456,57 - 41,29 * pH$$

Correlation: $r = -0,85$

Figure 7. Dependence of pH level on RE_{inf}

Scatterplot: pH vs. RE_{plant} (Casewise MD deletion)

$$RE_{plant} = 351,57 - 41,29 * pH$$

Correlation: $r = -0,85$

Figure 8. Dependence of pH level on RE_{plant}

Figure 9. Dependence of Eh_{min} on RE_{inf}

Figure 10. Dependence of Eh_{min} on RE_{plant}

Figure 11. Dependence of RE_{plant} on RE_{inf}

The general graph of the three most correlation-significant physicochemical parameters is shown in Figure 12. In volumetric form, it is seen that some points (Eh_{min} , RE_{plant} , RE_{inf}) are as close as possible to the surface, i.e. there is a very strong correlation between them. The farther the points are from the surface, the weaker the relationship.

Figure 12. Response surface of Eh_{min} from RE_{plant} and RE_{inf}

Based on mathematical and statistical analysis, it was found that physicochemical parameters in the range of values with very high correlation (r 0.9–1.0) includes the following indicators: pH , Eh_{min} , RE_{inf} , RE_{plant} .

Creation of tea-herbal compositions

The prospects of creating tea-herbal compositions based on ready-made dried mixtures have been confirmed by many authors (Alaşalvar, Çam, 2019; Tülek et al., 2020).

The composition of the tea-herbal mixture was obtained by mixing in the claimed ratio of dried and ground ingredients. Dried and crushed components were mixed in the following ratios: *Hibiscus sabdariffa* – 30 %; *Matricaria chamomilla* – 20 %; *Ilex paraguariensis* – 10 %; *Rosae fructus* – 10 %; *Mentha piperita* – 10 %; *Citrus sinensis* – 8 %; *Citrus limonum* – 7 %; *Calendulae flores* – 5 %. The resulting mixture was brewed in boiling water, kept for several minutes and consumed.

The rational concentration of the components of the mixture was chosen based on the sensory properties of the finished product. The results of sensory evaluation of tea-herbal compositions are shown in Figure 13. The highest score was obtained by tea-herbal composition – S.e. 9,1 points.

Figure 13. Sensory evaluation of tea-herbal compositions:

1 – color – 9.2 point (2 – homogeneous; 3 – red; 4 – pleasant; 5 – pronounced); 6 – infusion – 9.1 point (7 – bright; 8 – transparent; 9 – intensive); 10 – taste – 9.0 point (11 – pleasant; 12 – harmonious; 13 – palpable freshness; 14 – mild; 15 – tart; 16 – bitter; 17 – rich; 18 – smell/aroma – 9.1 point (19 – fragrant; 20 – floral; 21 – fresh; 22 – herbal; 23 – pronounced; 24 – pleasant; 25 – balanced)

The data obtained are correlated with the basic scientific concepts which are displayed in the works (Abdullah, Mazlan, 2020; Aboagye et al., 2021; Ağagündüz D., 2020; Bekhit et al., 2011; Chan et al., 2010; Gerolis et al., 2017; Gulua et al., 2018; Pérez-Burillo et al., 2018; Silka et al., 2016), regarding the processes of extracting of plant materials.

The developed composition of the tea and herbal mixture ensures the achievement of a synergistic effect, expressed in obtaining a new product with pleasant, harmonious sensory

properties (Chen et al., 2019; Feng et al., 2019; Guo et al., 2019; Li et al., 2019; Qi et al., 2018; Theuma, Attard, 2020; Xia et al., 2020; Xu et al., 2018; Zeng et al., 2017), high uniformity of distribution of flavoring and biologically active substances (Breiter et al., 2011; Bekhit et al., 2011; Hayat et al., 2015; Spizzirri et al., 2019; Xu et al., 2018).

A functional tea-herbal composition is perfect for everyday consumption, rich in vitamins and microelements, does not contain caffeine and allows you to get a high content of microelements necessary for a person (Aboagye et al., 2021; Guo et al., 2019; Feng et al., 2019; Chen et al., 2019; Hayat et al., 2015).

Conclusions

Based on the performed theoretical and experimental studies, the following conclusions can be drawn:

1. In the technology of beverages is promising to create tea-herbal compositions, the chemical composition of which includes plants that have bioactive compounds, in particular: catechins, polyphenols, vitamins, carotenoids.
2. Experimental studies show that all aqueous infusions of plant raw materials contain antioxidant systems. It was found that the recovery value of all the tested infusions is positive and ranges from (RE_{inf}) in the range from $RE_{inf} - 150.8$ mV (*Vitis vinifera*) to $RE_{inf} - 316.0$ mV (*Hibiscus sabdariffa*).
3. Based on mathematical and statistical analysis, it was found that physicochemical parameters in the range of values with very high correlation (r 0.9–1.0) includes the following indicators: pH , Eh_{min} , RE_{inf} , RE_{plant} .
4. For the restaurant business in the manufacture of beverages are promising water infusions of *Hibiscus sabdariffa* and *Citrus limonum*, which received increased antioxidant characteristics $RE_{inf} - 316.0$ mV and $RE_{inf} - 298.0$ mV, respectively.
5. Rational composition of tea-herbal composition was found: *Hibiscus sabdariffa* – 30 %; *Matricaria chamomilla* – 20 %; *Ilex paraguariensis* – 10 %; *Rosae fructus* – 10 %; *Mentha piperita* – 10 %; *Citrus sinensis* – 8 %; *Citrus limonum* – 7 %; *Calendulae flores* – 5 %.

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