Antioxidant properties of water-alcohol infusions of tea-herbal compositions based on yerba mate

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Abstract

Introduction. The aim of the research was to determine the antioxidant capacity of water-alcohol infusions of tea-herbal compositions based on yerba mate (*Ilex paraguariensis*) and evaluate their potential to be used in production of alcoholic beverages.

Materials and methods. Vegetable raw materials, namely *Ilex paraguariensis* and *Camellia sinensis* (fermented tea; partially fermented tea; unfermented tea) were used in the study. A water-alcohol mixture, 40% (alcohol by volume), was used as control. The antioxidant capacities of water-alcohol infusions of tea-herbal compositions were determined using the method of redox and pH-metry; sensory indicators were evaluated by the method of scoring with the definition of a complex indicator of quality.

Results and discussion. The antioxidant capacity of water-alcohol infusions of tea-herbal compositions was determined: active acidity, pH, ranging from 5.5 to –6.2 units pH; redox potential varied from 101.00 to 157.70 mV; recovery energy of infusions changed in diapason from 112.88 to 145.76 mV and the energy of reduction/oxidation of plant raw materials ranged from 28.34 to 61.22 mV. Water-alcohol infusions of tea-herbal compositions based on mate are characterized by high recovery energy 61.22 mV of and such indicators as: score, 9.63 points. The color tea-herbal compositions was light brown, the aroma was woody, the taste was sour-bitter, with a long-lasting bitter aftertaste, so they could be recommended to be used in the technology of alcoholic beverages in small quantities.

In the process of preparation of tea-herbal compositions, there was an increase in the indicators of the sensory evaluation in the mixtures based on tea/yerba mate in ratio 75 to 25: fermented tea/mate, 9.67 points; partially fermented tea/mate, 9.68 points; unfermented tea/mate, 9.71 points. A recipe composition of alcoholic beverages with a following composition has been developed: water-alcohol infusion of tea-herbal composition,%: fermented tea/mate, or partially fermented tea/mate, or unfermented tea/mate (in ratio 75:25), 38.5; brandy, 7.5; vanillin (1:10), 0.01; sugar syrup (65.8%), 53.1; citric acid, 0.3, «Caramel E 150», 0.6; ethyl alcohol and prepared water to ensure the strength of 20%.

Conclusion. The use of water-alcohol infusions of tea-herbal compositions based on yerba mate (*Ilex paraguariensis*), which have increased antioxidant characteristics and sensory indicators, was proposed for restaurant industry technology for the production of alcoholic beverages.

Introduction

Multi-component alcoholic drinks, namely infusions on plant materials, attract attention with the biologically active substances they contain. In the production of such alcoholic beverages natural plant extracts from herbaceous plants, wild fruits and berries, which have a pleasant taste and aroma, and are a rich source of biologically active compounds such as vitamins, minerals, polyphenols, and organic acids are used (Bravo et al., 2007; Gullón et al., 2018; Pluta-Kubica et al., 2020; Rebocho et al., 2022).

It is known that *Ilex paraguariensis* contains various compounds with high antioxidant activity (Dos Santos et al., 2017). Water-alcohol infusions obtained by extraction from dried leaves of this plant with a water-alcohol mixture possessed high antioxidant activity (Dos Santos et al., 2017). So, the creation of water-alcohol tinctures of tea-herbal compositions based on yerba mate (*Ilex paraguariensis*) containing substances with antioxidant properties will improve the quality and nutritional value of new alcoholic drinks.

The aim of the present research was to determine the antioxidant capacity of water-alcohol infusions of tea-herbal compositions based on yerba mate (*Ilex paraguariensis*) and evaluate their potential for restaurant industry technology for the production of alcoholic beverages. The creation of alcoholic beverages by introducing water-alcohol infusions of tea-herbal compositions with antioxidant properties allows restaurants to prepare new products that distinguish them from competitors and create a favorable image.

Materials and methods

Materials

The study used samples of plant raw materials, namely, *Ilex paraguariensis* and *Camellia sinensis* (fermented tea; partially fermented tea; unfermented tea). As a control sample a 40% (alcohol by volume) water-alcohol mixture was used.

Water-alcohol infusions preparation

Drying of plant raw materials was performed in order to reach a moisture content of 6–8%. Each dried plant raw materials, 4 g, and 100 ml of a water-alcohol mixture 40% (alcohol by volume) were placed in dark glass bottles. The vials were capped and placed in a dry-air thermostat DUROCELL 55 (BMT, Brno) for 48 hours at 40 ºC. The resulting infusions were cooled at 20 ºC, filtered and stored at 4ºC.

Determination of active acidity and redox potential

The active acidity was measured on a pH-meter «pH-150 MA» with a combined glass electrode «ESC 10601/4». Redox potential was measured on the pH-meter «pH-150M», by measuring the potential with a platinum redox electrode «ERP-105».

To evaluate the antioxidant properties of the water-alcohol plant extracts, the method, which is based on the difference of redox potentials in water-alcohol solutions, was used. This method allows to determine the total antioxidant activity of liquid products including complex mixtures and multifunctional antioxidants (Khareba et al., 2021; Kuzmin et al., 2020; 2021).

Determination of redox potential from hydrogen display in alcohols infusions of plant raw materials

For water-alcohol mixture, the relationship between hydrogen index (pH) and redox potential (Eh) was determined. It was shown that the change of pH of the water-alcohol mixture by 1 unit leads to a change in redox potential by 42 mV (Kuzmin et al., 2020):

$$Eh_{min} = 502–42 \cdot pH, mV, \quad (1)$$

In the range of values of the hydrogen index of 2.0–11.0 pH units for the water-alcohol mixture redox potential varies in the range of Eh_{min} 418.0–40.0 mV (Kuzmin et al., 2020).

The obtained values of the redox potential of the water-alcohol mixture Eh_{min} were correlated with the actually measured values of the redox potential of alcohol infusions (RE_{inf}) from plant raw materials by the platinum electrode (Eh_{act}), which characterizes the difference of these values (RE_{inf}) (Kuzmin et al., 2020):

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

The energy of reduction/oxidation process of plant raw materials (RE_{plant}) is determined by the difference between of alcohol infusions from plant raw materials (RE_{inf}) and solvent (control) (Kuzmin et al., 2020):

$$RE_{plant}=RE_{inf}–RE_{sol}, mV$$

According to the results of research, an optimized method to assess the antioxidant capacity of alcohol infusions from plant raw materials has been developed (Kuzmin et al., 2020).

Sensory evaluation

The sensory evaluation (S. e.) of the obtained infusions was carried out with a point scale with the involvement of highly qualified and experienced experts in the field of alcoholic beverages assessment.

Results and discussions

Antioxidant capacity and sensory evaluation of water-alcohol tea-herbal infusions

The physico-chemical and sensorial indicators of obtained water-alcohol tea-herbal infusions are presented in Table 1.

Table 1

Characteristics of water-alcohol infusions

Parameters	Extractant (water-alcohol mixture)	Water-alcohol infusion of			
		fermented tea	partially fermented tea	unfermented tea	mate
Active acidity, pH	5.63	5.51	5.91	6.20	5.77
Eh_{min}, mV	265.54	270.58	253.78	241.60	259.66
Eh_{act}, mV	181.00	157.70	119.50	101.00	113.90
RE_{inf}, mV	84.54	112.88	134.28	140.60	145.76
RE_{plant}, mV	0.00	28.34	49.74	56.06	61.22
S.e., points	9.50	9.61	9.64	9.67	9.63

Note: Eh_{min}, the minimum theoretical value of redox potential; Eh_{act}, actual value of redox potential; RE_{inf}, recovery energy of infusions; RE_{plant}, the energy of reduction/oxidation of vegetable raw materials; S.e., sensory evaluation indicators.

A water-alcohol mixture was used as a solvent with pH 5.63; Eh_{min}, 265.54 mV; Eh_{act}, 181.00 mV; RE, 84.54 mV; S.e. 9.50 points (color – colorless; aroma – alcoholic; taste – moderately burning, empty). For the fermented tea water-alcohol infusions the pH reached the value of 5.51, while in the case of partial fermented tea this value was 5.91 and for unfermented tea – 6.20 pH units. It can be concluded that the tea degree of oxidation/fermentation contributes to the change in the pH level. It is known that unfermented tea (green, white tea) is not subject to oxidation, or low oxidation, while partially fermented tea (red, yellow tea) are subjected to partial oxidation and fermented tea (black tea) is completely oxidized. This is explained by the presence of organic acids in tea that undergo changes during the fermentation process (Yu et al., 2022). The value of RP (Eh_{min} for water-alcohol tea-herbal infusions was obtained, which has a value from 241.60 (unfermented tea) to 270.58 mV (fermented tea); the actual measured RP of water-alcohol tea-herbal infusions (Eh_{act}) – from 101.00 (unfermented tea) to 157.70 mV (fermented tea).

The regenerative capacity (recovery energy, RE_{inf}) of water-alcohol tea-herbal infusions ranged within the limits: from RE_{inf}, 112.88 for fermented tea to RE_{inf}, 145.76 mV for mate tea. The reduction/oxidation energy of tea-herbal plant materials (RE_{plant}) relative to the solvent – water-alcohol mixture was in the range of values from 28.34 (fermented tea) to 61.22 mV (mate tea). It can be concluded that water-alcohol tea-herbal infusions are depending on the activity of plant raw materials and have a regenerative capacity (over 0 mV) – 100% of samples. In addition to physical and chemical indicators, water-alcohol tea-herbal infusions had excellent sensory scores (S.e.), which depend on the degree of tea fermentation. The fermented tea obtained a score of S.e., 9.61 points (color – dark brown; aroma – tea, woody; taste – moderately burning, very astringent), while the unfermented tea registered a value of S.e., 9.67 points – (color – brownish brown; aroma – tea, fragrant; taste – sour-bitter, astringent).

At the first stage, it can be concluded that the sample of water-alcohol tea-herbal infusion of unfermented tea is the most promising, which has a high sensory score of 9.67 points and can be recommended in the technology of alcoholic beverages.

Antioxidant and sensory evaluation of the water-alcohol infusion of mate

Biological effect of tea depends on the degree of its oxidation/fermentation, which is explained by the change in the antioxidant activity of chemical compounds present in tea, especially flavonoids and phenolic acids (Oh et al., 2013; Sentkowska and Pyrzynska, 2018; Silveira et al., 2014; Zielinski et al., 2014). The water-alcohol infusion of mate, prepared from yerba mate (*Ilex paraguariensis*), had the following physical and chemical characteristics: pH 5.77; Eh_{min} 259.66 mV; Eh_{act} 113.90 mV; RE_{inf} 145.76 mV; RE_{inf} 61.22 mV. Comparing this characteristics with those of the water-alcohol infusions of tea, depending on the degree of fermentation, allows us to state the following: the antioxidant capacity of the water-alcohol infusion of mate (RE_{inf} 145.76 mV) is 54% higher compared to the water-alcohol infusion of fermented tea (RE_{inf} 112.88 mV); 19% higher compared to the water-alcohol infusion of partially fermented tea (RE_{inf} 134.28 mV); 8% higher compared to the water-alcohol infusion of unfermented tea (RE_{inf} 140.60 mV). The antioxidant capacity of raw mate (RE_{plant} 61.22 mV) is 23% higher compared to fermented tea (RE_{plant} 28.34 mV); 8% higher compared to partially fermented tea (RE_{plant} 49.74 mV); 4% higher compared to unfermented tea (RE_{plant} 56.06 mV). This can be explained by the presence of several biologically active compounds: caffeic acid ← hydroxycinnamic acids ← phenolic acids ← simple phenols ← phenolics (Anesini et al., 2012; Riachi et al., 2018; Souza et al., 2011; 2015; Yang and Liu, 2013; Zielinski et al., 2014); gallic acid ← hydroxybenzoic acids ← phenolic acids ← simple phenols ← phenolics (Zielinski et al., 2014); catechins; epicatechin; rutin ← flavonols ← flavonoids ← polyphenols

← phenolics (Anesini et al., 2012; Bravo et al., 2007; Mazzafera, 1997; Zielinski et al., 2014); procyanidin B2 ← condensed ← tannins ← non-flavonoids ← polyphenols ← phenolics (Zielinski et al., 2014); particularly caffeoyl derivatives ← chlorogenic acids (Anesini et al., 2012; Bravo et al., 2007; Marques and Farah, 2009; Wan et al., 2021; Zang et al., 2003); quercetrin; caffeine ← methylxanthines ← purine alkaloids (Zielinski et al., 2014).

Therefore, water-alcohol infusion of tea can be recommended in the technology of alcoholic beverages in a smaller amount than mate infusions, due to specific sensory indices: color – light brown; aroma – woody; taste – sour-bitter, with a long-lasting bitter aftertaste (S.e. 9.63 points). Similar results were stated by Godoy et al. (2013), who characterized the sensory properties of mate infusions: color – light green; aroma – specific; taste – characteristically bitter, reminiscent of strong green tea.

Antioxidant capacity of water-alcohol tea-herbal infusions

The potential of creating tea-herbal compositions based on ready-made dried mixtures have been confirmed by many authors (Alaşalvar and Çam, 2019; Tülek et al., 2020). A functional tea-herbal composition is perfect for everyday consumption, rich in vitamins and microelements, does not contain caffeine and allows to get a high content of microelements necessary for a person (Chen et al., 2019; Feng et al., 2019; Guo et al., 2019).

Water-alcohol tea-herbal infusions and their combinations are promising for restaurants in the production of alcoholic beverages, which allow to obtain increased antioxidant characteristics and positive sensory scores (Figure 1–3). This is supported by the research of Bravo et al., 2007, where is proved that mate has slightly higher antioxidant activity than black tea, but lower than green tea. At the same time, content of total phenolic compounds of the *Ilex paraguariensis* extract is higher than that of green tea (Bravo et al., 2007; Gugliucci et al., 2009; Lunceford and Gugliucci, 2005; Zielinski et al., 2014). This confirms the ability to inhibit the formation of *Ilex paraguariensis* glycation end products compared to green tea (Lunceford and Gugliucci, 2005) and to prevent lipid peroxidation (Barg et al., 2014). While individual phenolic compounds: gallic acid, epicatechin, procyanidin B2 and quercitrin are present only in *Camellia sinensis* teas (Zielinski et al., 2014).

The physicochemical and sensory evaluation indicators of water-alcohol infusions of tea-herbal compositions (fermented tea; partially fermented tea; unfermented tea; mate) are given depending on the mass fraction of their mixtures (ω, %) in steps of 25% (Figure 1–3), with further modeling of the rational composition of water-alcohol infusions for the production of high-quality alcoholic beverages.

It was established that the existing combinations (ω, % 100/0; 75/25; 50/50; 25/75; 0/100) fermented tea/mate (Figure 1); partially fermented tea/mate (Figure 2); unfermented tea/mate (Figure 3) make it possible to expand the ranges of the rational composition of alcohol infusions of tea-herbal compositions when modeling a qualitative composition.

According to the research results, it was established that in the process of mixing tea-herbal compositions, there is an upward of sensory evaluation scores – for mixtures ω,% 75/25: for fermented tea/mate – S.e. 9.67 points (Figure 1, f), partially fermented tea/mate – S.e. 9.68 points (Figure 2, f); unfermented tea/mate – S.e. 9.71 points (Figure 3, f).

The developed composition of the tea and herbal mixture ensures the obtaining a new product with pleasant, harmonious sensory properties and high uniformity of distribution of flavoring and biologically active substances. This confirms the potential of using *Ilex paraguariensis* for the production of beverages as it was proposed in the studies (Esmelindro et al., 2004; Mesquita et al., 2021; Souza et al., 2015).

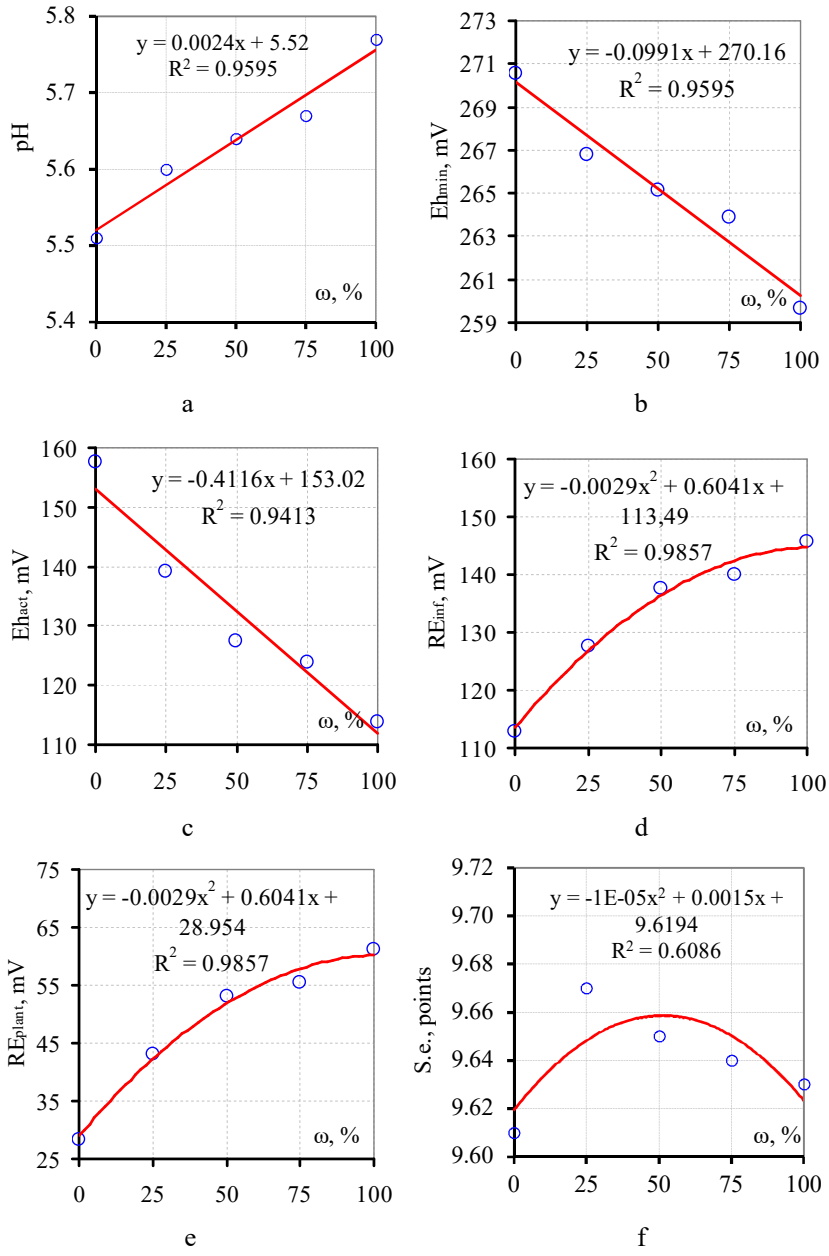

Figure 1. Characteristics of water-alcohol infusions of tea-herbal compositions depending on the mass fraction of fermented tea and mate (ω):
a, active acidity (pH); b, the minimum theoretical value of RP (Eh_{min}); c, actual measured of RP (Eh_{act}); d, recovery energy of infusions (RE_{inf}); e, the energy of reduction/oxidation of vegetable raw materials (RE_{plant}); f, sensory evaluation indicators (S.e.);
combination of fermented tea/mate (ω, %, 100/0; 75/25; 50/50; 25/75; 0/100).

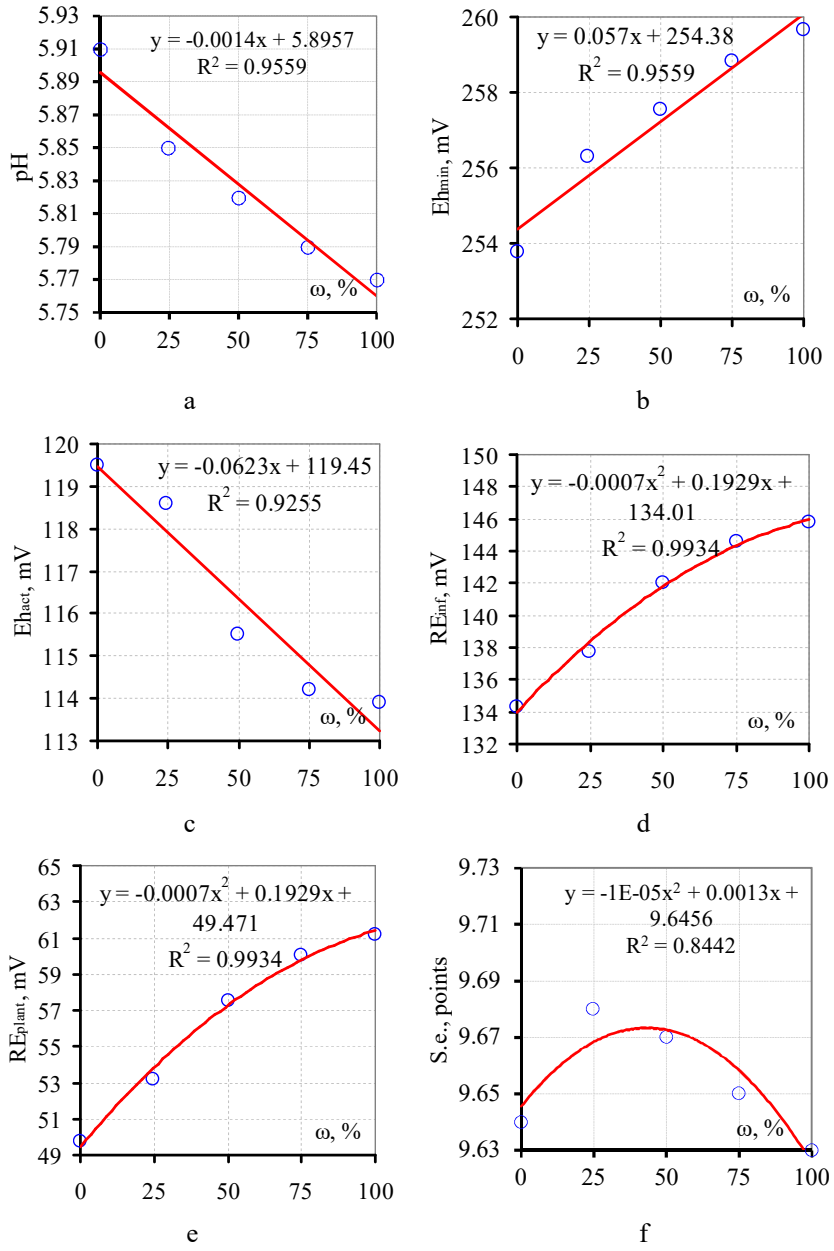

Figure 2. Characteristics of water-alcohol infusions of tea-herbal compositions depending on the mass fraction of partially fermented tea and *mate* (*ω*):

a, active acidity (pH); b, the minimum theoretical value of RP (Eh_{min}); c, actual measured of RP (Eh_{act}); d, recovery energy of infusions (RE_{inf}); e, the energy of reduction/oxidation of vegetable raw materials (RE_{plant}); f, sensory evaluation indicators (S.e.);
partially fermented tea/mate combinations (ω, %, 100/0; 75/25; 50/50; 25/75; 0/100).

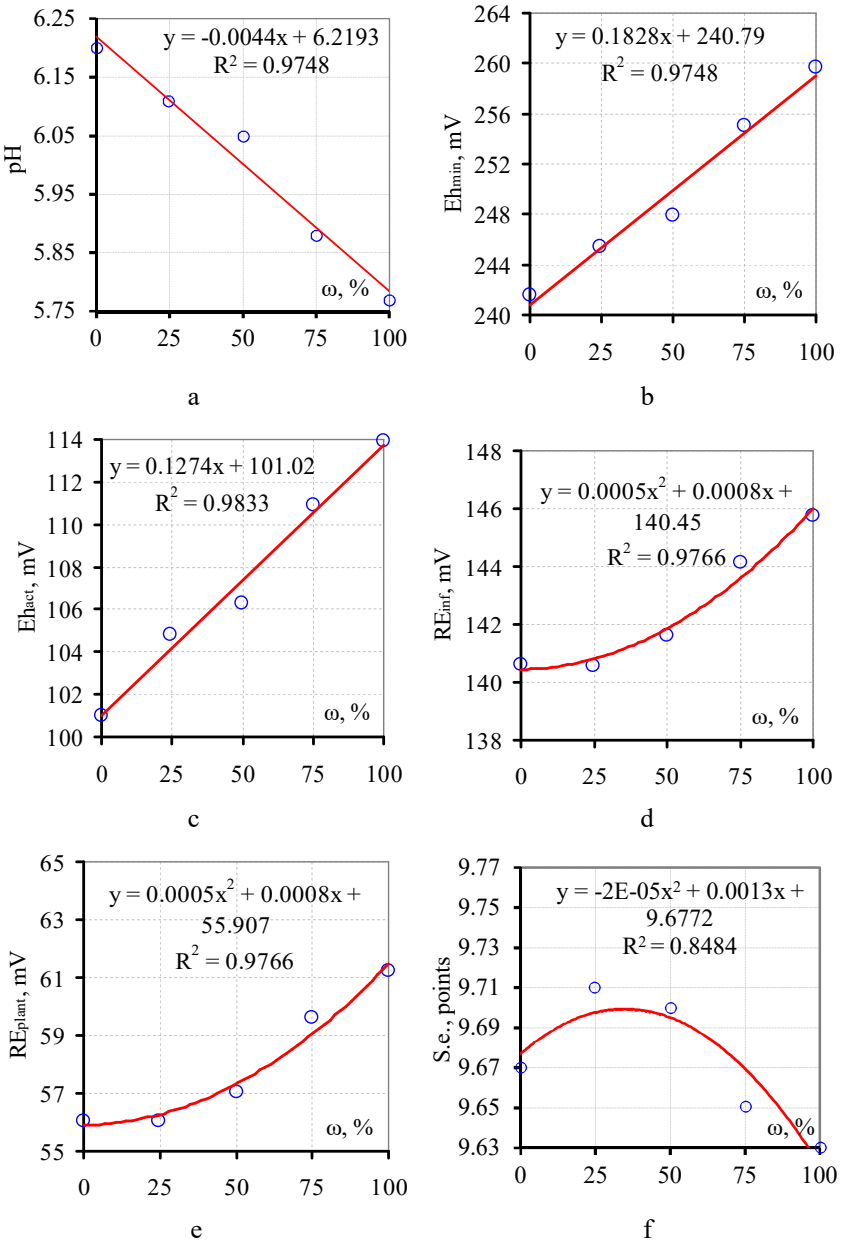

Figure 3. Characteristics of water-alcohol infusions of tea-herbal compositions depending on the mass fraction of unfermented tea and mate (*ω*):
a, active acidity (pH); b, the minimum theoretical value of RP (Eh_{min}); c, actual measured of RP (Eh_{act}); d, recovery energy of infusions (RE_{inf}); e, the energy of reduction/oxidation of vegetable raw materials (RE_{plant}); f, sensory evaluation indices (S.e.);
unfermented tea/mate combinations (ω,% 100/0; 75/25; 50/50; 25/75; 0/100).

Tea-herbal compositions

As a result of the conducted research, the composition of an alcoholic drink was proposed. In the basic recipe compositions of fermented tea/mate, or partially fermented tea/mate, or unfermented tea/mate (ω, %, 75/25) water-alcohol infusions, were added, which allows increasing the redox and consumer properties of the finished product.

To obtain the new alcoholic beverage, the following was used: water-alcohol infusion of tea-herbal composition (fermented tea/mate, or partially fermented tea/mate, or unfermented tea/mate ω,% 75/25) – 38.49%, brandy – 7.54%, vanillin – 0.01%, sugar syrup (65.8%) – 53.08%, citric acid – 0.28%, «Caramel E 150» – 0.6%. Water-alcohol infusions were prepared based on 20% (alcohol by volume) (Figure 4).

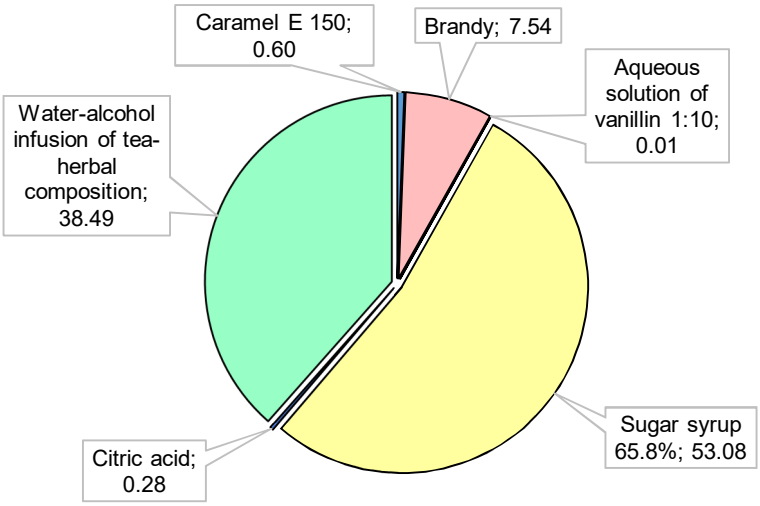

Figure 4. Blending of alcoholic beverage, %

It can be argued that the range of alcoholic beverages and its variety are combined with the possibility of mixing alcohol with many ingredients. Thanks to the different ratio of tea-herbal compositions, new flavors appear that are completely different from each other, as well as various useful properties (Khareba et al., 2021; Kuzmin et al., 2020; 2021). But among all the useful properties, the main thing will be to change the redox reactions (Gullón et al., 2018). The developed composition of the tea and herbal mixture ensures the obtaining of a new product with pleasant, harmonious sensory properties.

Conclusions

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

1. It was found that the values of the antioxidant capacity of water-alcohol infusions of tea-herbal compositions: active acidity was in the range from 5.5 to 6.2 pH units; RP (Eh_{act}), 101.00-157.70 mV; recovery energy of infusions (RE_{inf}), 112.88-145.76 mV;

the energy of reduction/oxidation of plant raw materials (RE_{plant}), 28.34-61.22 mV.

2. The high recovery energy (61.22 mV) of tea herbal infusions based on mate makes them promising for restaurants in the production of alcoholic beverages and in the production of alcoholic beverages. According to the organoleptic evaluation, the mixtures differ in light brown color, woody aroma, sour-bitter taste with a long-lasting bitter aftertaste.
3. In order to obtain tea herbal infusions based on mate (*Ilex paraguariensis*), the optimal blending ratio has to be: fermented tea/mate (ω, %, 75/25), partially fermented tea/mate (ω, %, 75/25) unfermented tea/mate (ω, %, 75/25).
4. A recipe composition of alcoholic beverages with a rational composition has been developed: water-alcohol infusion of tea-herbal composition (fermented tea/mate, or partially fermented tea/mate, or unfermented tea/mate ω, %, 75/25) – 38.49%, brandy – 7.54%, vanillin 1:10 – 0.01%, sugar syrup (65.8%) – 53.08%, citric acid – 0.28%, «Caramel E 150» – 0.6%, ethyl alcohol and water are prepared – based on the strength of 20%.

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