

Antioxidant capacity of alcoholic beverages based on infusions from non-traditional spicy-aromatic vegetable raw materials

Oleg Kuzmin¹, Volodymyr Kucherenko²,
Iryna Sylka¹, Volodymyr Isaienko³, Yuliia Furmanova¹,
Olena Pavliuchenko¹, Viacheslav Hubenia¹

1 – National University of Food Technologies, Kyiv, Ukraine

2 – Ukrainian Corporation for Viticulture and Wine Industry "Ukrvinprom"

3 – National Aviation University, Kyiv, Ukraine

Abstract

Keywords:

Spicy-aromatic
Antioxidant
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Infusion
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Introduction. The aim of the study is to determine the antioxidant capacity of aqueous-alcoholic infusions using non-traditional spicy-aromatic raw materials in the technology of alcoholic beverages.

Materials and methods. Antioxidant ability of infusions of spicy-aromatic plants: *Perilla frutescens*; *Elsholtzia stauntonii* Benth; *Artemisia abrotanum*; *Monarda didyma*; *Agastache foeniculum*; *Satureja hortensis*; *Ruta graveolens*; *Nepeta transcaucasica* Grossch was determined by redoxmetry and pH-metry; sensory evaluation – by expert method; the results of mathematical and statistical processing – by the method of linear Pearson correlation.

Results and discussion. The minimum theoretical value of redox potential (*RP*) for plant aqueous-alcoholic infusions was obtained, which has a value from 228.0 mV (*Satureja hortensis*) to 260.4 mV (*Agastache foeniculum*). The actual measured *RP* of infusions was established – from 117 mV (*Elsholtzia stauntonii* Benth) to 134 mV (*Nepeta transcaucasica* Grossch). The hydrogen index for aqueous-alcoholic infusions from spicy-aromatic raw materials has a value of 6.66 units pH (*Agastache foeniculum*) to 7.20 units pH (*Satureja hortensis*). Aqueous-alcoholic infusions from vegetable raw materials and a volume fraction of ethanol of 40% have the value of recovery energy (*RE*) in the range from 100.0 mV (*Nepeta transcaucasica* Grossch) to 138.2 mV (*Ruta graveolens*).

Aqueous-alcoholic infusions from spicy-aromatic raw materials have values of sensory evaluation (*S.e.*) from 9.50 to 9.69 points. The highest value of *S.e.* 9.69 points is characteristic of *Nepeta transcaucasica* Grossch: color – light brown; taste – mint; aroma – soft, pleasant, sweet.

Conclusion. It is proposed for the technology of alcoholic beverages the use of aqueous-alcoholic infusions from *Ruta Graveolens* and *Nepeta transcaucasica* Grossch, which received increased antioxidant characteristics *RE* 138.2 mV and *RE* 100.0 mV, respectively, and positive *S.e.* 9.57 and *S.e.* 9.69 points on a 10-point scale.

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Corresponding author:

Oleg Kuzmin

E-mail:

kuzmin_ovl@ukr.net

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Introduction

One of the important directions of food industry development is improvement of taste, aroma of food, preservation (or addition) of nutritional value of the final product (Dubovkina I. et al., 2019; Kuzmin et al., 2016; Kuzmin et al., 2017) [1–3].

Currently, the use of vegetable raw materials in the technology of alcoholic beverages is very relevant (Andreou et al., 2018; Chandrasekara, Shahidi, 2018; Iannitti, Palmieri, 2009; Halliwell, Gutteridge, 1990; Kawa-Rygielska et al., 2019; Fotakis et al., 2016 [4–9], especially when used in restaurant business. Herbal beverages commonly consumed worldwide contain different chemical substances that display a broad spectrum of biological activities (Kamdem et al., 2013; Frolova et al., 2019; Gerolis et al., 2017; Imark et al., 2000; Pyrzynska, Sentkowska, 2019; Wong et al., 2020; Sentkowska, Pyrzynska, 2018; Siddiqui et al., 2018; Steenkamp et al., 2004) [10–18]. They have gained growing interest among scientists and consumers due to their antioxidant properties (Breiter et al., 2011; Dube et al., 2017 [19, 20]. The ability of plant phenolics to act as free radical scavengers has led to increased interest in their ability to act as antioxidants (Keating et al., 2014; Oh et al., 2013; Herrera et al., 2018; Humia et al., 2020) [21–24]. Antioxidants are able to reduce the output of oxidation products: hydroperoxides, alcohols, aldehydes, ketones, fatty acids.

Beverages are rich sources of natural bioactive compounds such as carotenoids, phenolic acids, flavonoids, coumarins, alkaloids, polyacetylenes, saponins and terpenoids, among others (Ruiz-Ruiz et al., 2020; Naithani et al., 2006) [25, 26]. Of particular interest in the production of alcoholic beverages is a spicy-aromatic raw material that exhibits antioxidant and tonic properties (Vergun et al., 2018; Vergun et al., 2019; Kurylo et al., 2018) [27–29]. At present, the antioxidant characteristics of all prescription components, food additives, biologically active substances and their combinations have not been sufficiently studied (Buglass et al., 2012; Grunert et al., 2018; Gullón et al., 2018; Gulua et al., 2018; Joubert, Beer, 2012) [30–34].

RP is an important indicator of the biological activity of solutions (Kuzmin O. et al., 2016; Merwe et al., 2017) [2, 35]. It characterizes the deviation from the ionic balance of free electrons in a liquid medium. Changing the concentration of free electrons leads to a change in its electron charge and, accordingly, the *RP*. If the *RP* is positive, it indicates the oxidizing ability of the solution, negative indicates recovery ability. The value of *RP* allows to estimate the energy of processes, that is, characterizes the activity of ions in redox reactions (Bahir, 1999; Priluckij, 1997) [36, 37]. Therefore, in order for the human body to optimally use in the exchange processes aqueous-alcoholic mixtures and food, the *RP* values must correspond to the *RP* values of the internal environment of the organism, or have more negative values (Bahir, 1999) [36].

But among all the useful properties, the main thing will be to change the redox reactions (Priluckij, 1997) [37]. Redox reactions affect the ratio of energy to support homeostasis – relativity of dynamic constancy of composition and properties of internal environment and stability of basic physiological functions of an organism. This ensures the vital activity of any organism. The magnitude of this rate depends on the ratio and concentration of oxidized and reduced substances in the body, including substances coming from food and beverages, so one of the main factors in the regulation of redox reactions is the redox potential (Kuzmin O. et al., 2016; Bahir, 1999; Priluckij, 1997) [2, 36, 37].

These circumstances determine the relevance of this work, which is to develop aqueous-alcoholic infusions of vegetable raw materials in the technology of alcoholic cocktails for restaurants. Creating alcoholic cocktails with reduced toxicity through the introduction of spicy-aromatic infusions with antioxidant properties, allows restaurant establishments to create new products, which favorably differentiates them from competitors, creating a favorable image of

the institution, which cares for the protection of consumers.

The *purpose* of the work is to develop the scientific bases of antioxidant activity of aqueous-alcoholic infusions from vegetable raw materials and to identify the most promising plants as sources of natural antioxidants in the creation of alcoholic beverages.

It is necessary to solve the following *problems*:

- To substantiate the prospect of using aqueous-alcoholic infusions from vegetable raw materials in the production of alcoholic beverages;
- To establish the value of the restorative capacity of aqueous-alcoholic infusions from vegetable raw materials;
- To develop statistics on the frequency of values in a certain range of the data obtained during sensory evaluation and physicochemical values;
- To carry out mathematical and statistical analysis of indicators of aqueous-alcoholic infusions and establish internal correlation;
- Identify the most promising sources of natural antioxidants for use in alcoholic beverage technology.

Materials and methods

Materials

The study used plant raw materials that are allowed to be used in the production of alcoholic beverages. In the *M.M. Gryshko National Botanic Garden of NAS of Ukraine* was created new cultures of spicy-aromatic plants, which became the subject of these studies (Rakhmetov, 2011) [38].

In the Figure 1 shows a photo of vegetable raw materials: *Perilla frutescens*; *Elsholtzia stauntonii Benth*; *Artemisia abrotanum*; *Monarda didyma*; *Agastache foeniculum*; *Satureja hortensis*; *Ruta graveolens*; *Nepeta transcaucasica Grossch.* For preparation of extracts used the following basic raw materials: ethanol rectified, water, cardboard filtering.

The extracts should meet the requirements on sensory evaluation (Table 1). The extracts must meet the requirements by physicochemical parameters (Table 2).

Table 1

Sensory evaluation of extract

Indicator	Characteristic
Appearance	Transparent without sediment and foreign impurities fluid, acceptable opalescence that disappears after filtration
Color, taste, aroma	The inherent vegetable raw materials from which they are made, without the foreign taste and odor

Table 2

Physicochemical parameters of extract

Parameter	Norm
Ethyl alcohol by volume, %	20.0–90.0
Mass fraction of essential oil, %	0.0–15.0
Mass concentration of the total extract, g/100 cm ³	0.1–20.0



Figure 1. Photo of vegetable raw materials:

a – *Perilla frutescens*; b – *Elsholtzia stauntonii* Benth; c – *Artemisia abrotanum*; d – *Monarda didyma*; e – *Agastache foeniculum*; f – *Satureja hortensis*; g – *Ruta graveolens*; h – *Nepeta transcaucasica* Grossch

Aqueous-alcoholic infusion – semi-finished product, which is prepared by extraction of raw materials in aqueous-alcoholic solution with a strength of 40 %. The static method of extraction is called maceration. The tested aromatic raw material (dry) was infused in a aqueous-alcoholic mixture in this work.

Description of research procedure

The first stage – the preparation of infusions. Plant raw materials were minced into a size of 3x3 mm (Figure 2), suspensions of 4 g were placed into the glass bottles, were filled by 100 ml of alcohol solvent with volume fraction of rectified ethyl alcohol 40 %. The resulting infusions were cooled to 20 °C for 7 days, stirring periodically.

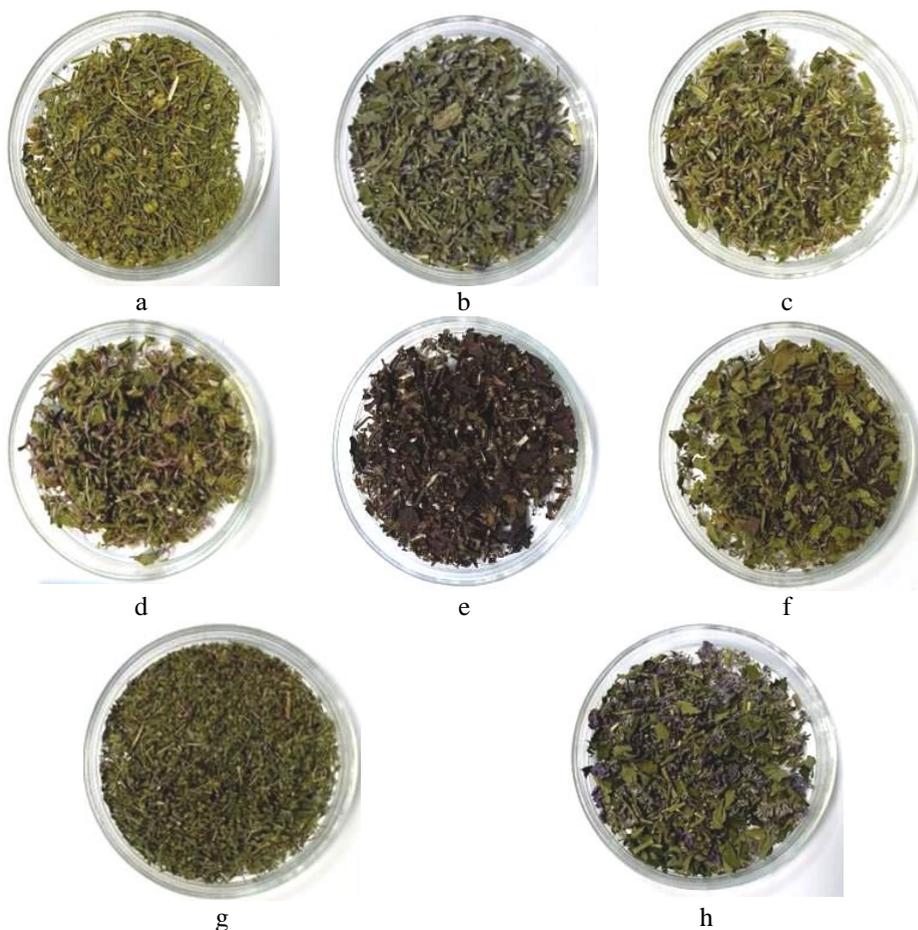


Figure 2. Photo of Samples of crushed plant raw materials:

a – *Perilla frutescens*; b – *Elsholtzia stauntonii* Benth; c – *Artemisia abrotanum*; d – *Monarda didyma*; e – *Agastache foeniculum*; f – *Satureja hortensis*; g – *Ruta graveolens*; h – *Nepeta transcaucasica* Grossch.

Next, 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.

Description of methods

Expert method of sensory evaluation. The expert method of determination of values of indexes of quality is based on the account of opinions of group highly skilled specialists-experts. (The expert of – it a specialist on the certain type of object which owns the increased sensitiveness to properties of this object) (Kuzmin et al., 2016; Kuzmin et al., 2017) [2, 3].

Methods for determining antioxidant capacity. To evaluate the antioxidant properties of the obtained aqueous-alcoholic plant infusions, the *method* (Priluckij, 1997) [37], based on the difference of *RP* in inactivated inorganic solutions and complex biochemical media. 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., 2016) [2].

Formula (1) holds for inactivated inorganic solutions in equilibrium. This formula links the active acidity of the *pH* and the *RP* (Priluckij, 1997) [37]:

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

where Eh_{min} – the minimum theoretically expected value of the *RP*;
pH – active acidity of the test solution.

Acquired *RP* values were compared with actual measurements of Eh_{act} solution. The change of the *RP* toward the recovery energy (*RE*) was determined by the formula:

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

where *RE* – the shift of *RP* to the side of recovered meanings (resilience);

Eh_{min} – minimal theoretically expected meaning of *RP*;

Eh_{act} – actual measured *RP*.

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 3) interpretation for behavioral sciences offered by Hinkle et al., 2003 [39].

Table 3

Correlation coefficient interpretation

Absolute value of coefficient (<i>r</i>)	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) [39, 40].

Results and discussions

Sensory evaluation

The results of sensory evaluation (Kuzmin et al., 2017) [3] of the obtained infusions on the extractant are presented in the Table 4 and Figures 3.

Sensory evaluation (S.e.) of extracts

Table 4

Plant raw materials	Color	Aroma	Test	S.e., points
1. <i>Perilla frutescens</i>	Light amber	Floral	Sour-bitter, tart, unpleasant	9.50
2. <i>Elsholtzia stauntonii</i> Benth	Light brown	Grassy, floral	Sour-bitter	9.64
3. <i>Artemisia abrotanum</i>	Thatched	Grassy	Bitter, with a long, bitter aftertaste	9.51
4. <i>Monarda didyma</i>	Thatched	Fragrant, floral	Sour-bitter, unpleasant, with a bitter aftertaste	9.52
5. <i>Agastache foeniculum</i>	Light amber	Bright ethereal, herbal, fragrant	Bitter, tart	9.65
6. <i>Satureja hortensis</i>	Light brown	Spicy, fragrant, herbal	Moderately hot, irritable, with a sweet taste	9.67
7. <i>Ruta graveolens</i>	Thatched	Fragrant, grassy, floral	Bitter, tart	9.57
8. <i>Nepeta transcaucasica</i> Grossch	Light brown	Mint	Soft, pleasant, sweet	9.69
9. Extractant – aqueous-alcoholic mixture	Transparent	Alcoholly	Abrupt	9.57

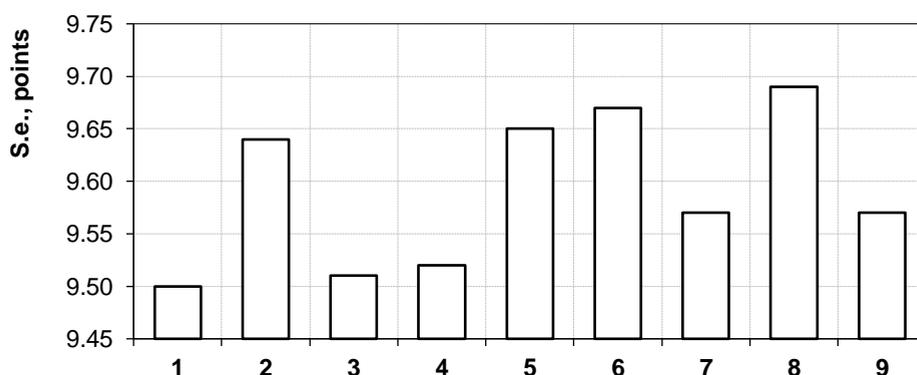


Figure 3. Sensory evaluation indicators of extracts on the extractant:

- 1 – *Perilla frutescens*; 2 – *Elsholtzia stauntonii* Benth; 3 – *Artemisia abrotanum*;
 4 – *Monarda didyma*; 5 – *Agastache foeniculum*; 6 – *Satureja hortensis*;
 7 – *Ruta graveolens*; 8 – *Nepeta transcaucasica* Grossch; 9 – aqueous-alcoholic mixture

Antioxidant capacity

Physicochemical studies, namely determination of the *pH* level and *RP* (Prévost, Brillet-Viel, 2014; Nicoli et al., 2004) [41, 42], were performed according to the method (Priluckij, 1997) [37] and calculations given above (Kuzmin et al., 2016) [2]. As a result of extraction received infusions (Andreou et al., 2018; Chandrasekara, Shahidi, 2018; Iannitti, Palmieri, 2009; Halliwell, Gutteridge, 1990; Kawa-Rygielska et al., 2019) [4-8], physicochemical indicators (Breiter et al., 2011; Dube et al., 2017 [19, 20] of which are presented in the Table 5.

Table 5

Quality indicators of extracts on extractant

Plant raw materials	<i>t</i> , °C	<i>pH</i>	<i>Eh_{min}</i> , mV	<i>Eh_{act}</i> , mV	<i>RE</i> , mV
1. <i>Perilla frutescens</i>	18	7.07	235.8	123	112.8
2. <i>Elsholtzia stauntonii</i> Benth	17	7.04	237.6	117	120.6
3. <i>Artemisia abrotanum</i>	16	7.18	229.2	118	111.2
4. <i>Monarda didyma</i>	17	6.79	252.6	132	120.6
5. <i>Agastache foeniculum</i>	17	6.66	260.4	132	128.4
6. <i>Satureja hortensis</i>	17	7.20	228.0	125	103.0
7. <i>Ruta graveolens</i>	16	6.73	256.2	118	138.2
8. <i>Nepeta transcaucasica</i> Grossch	19	7.10	234.0	134	100.0
9. <i>Aqueous-alcoholic mixture</i>	18	7.96	182.4	180	2.4
min	16	6.66	228.0	117	100.0
max	19	7.20	260.4	134	138.2

where: *t* – temperature of infusion; *pH* – active acidity of the test solution; *Eh_{min}* – minimal theoretically expected meaning of *RP*; *Eh_{act}* – actual measured *RP*; *RE* – recovery energy

Figures 4–7 show graphically the change in the physicochemical indicators of the quality of extracts of spicy-aromatic raw materials on the extractant.

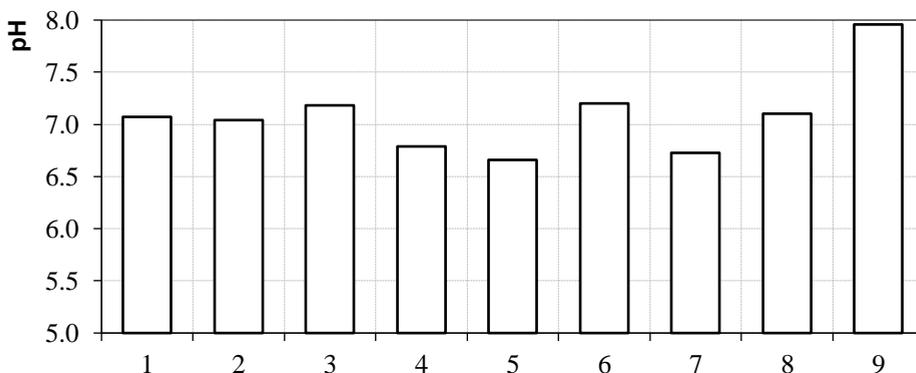


Figure 4. Hydrogen index (pH) of infusions of the investigated raw material:

1 – *Perilla frutescens*; 2 – *Elsholtzia stauntonii* Benth; 3 – *Artemisia abrotanum*;
4 – *Monarda didyma*; 5 – *Agastache foeniculum*; 6 – *Satureja hortensis*; 7 – *Ruta graveolens*;
8 – *Nepeta transcaucasica* Grossch; 9 – *Aqueous-alcoholic mixture*

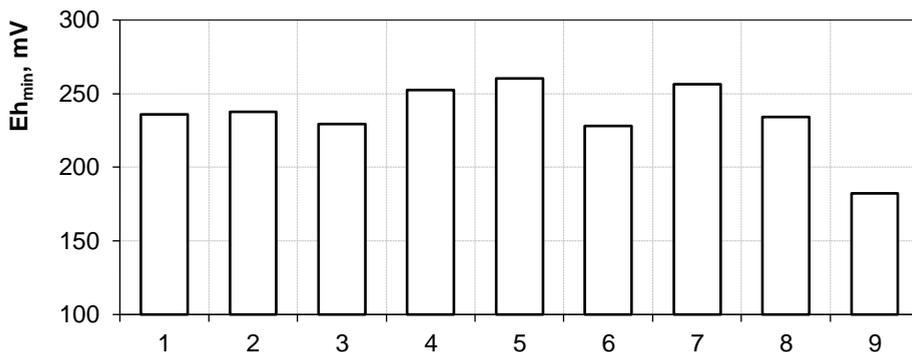


Figure 5. The minimum theoretical value of RP ($E_{h_{min}}$) of infusions of the investigated raw material

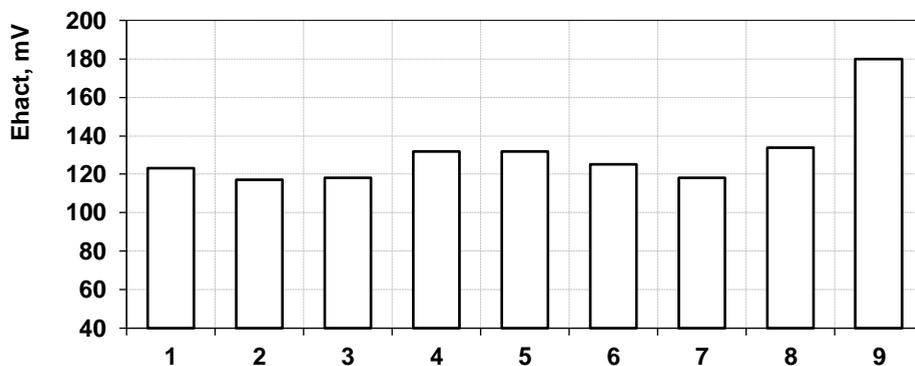


Figure 6. The actual measured RP of infusions ($E_{h_{act}}$) of infusions of the investigated raw material

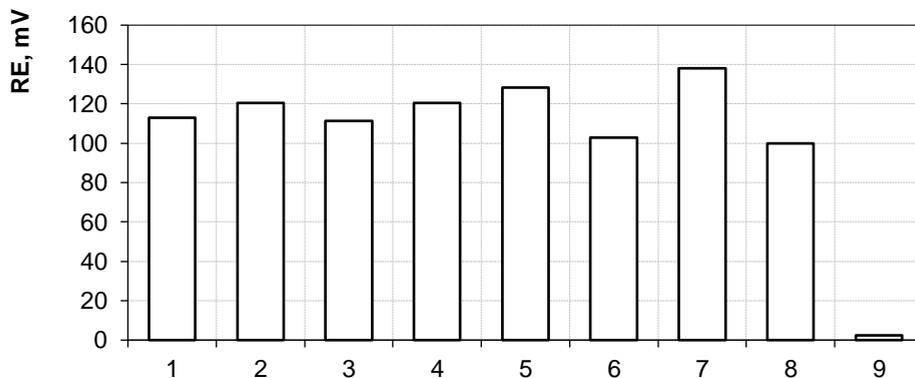


Figure 7. Recovery energy (RE) of infusions of the investigated raw material

For Figures 5–6: 1 – *Perilla frutescens*; 2 – *Elsholtzia stauntonii* Benth; 3 – *Artemisia abrotanum*; 4 – *Monarda didyma*; 5 – *Agastache foeniculum*; 6 – *Satureja hortensis*; 7 – *Ruta graveolens*; 8 – *Nepeta transcaucasica* Grossch; 9 – Aqueous-alcoholic mixture

The minimum theoretical value of RP (Eh_{min}) for plant aqueous-alcoholic infusions (Priluckij, 1997) [37] was obtained, which has a value from 228.0 mV (*Satureja hortensis*) to 260.4 mV (*Agastache foeniculum*). The actual measured RP of infusions (Eh_{act}) was established – from 117 mV (*Elsholtzia stauntonii* Benth) to 134 mV (*Nepeta transcaucasica* Grossch). The hydrogen index for aqueous-alcoholic infusions from spicy-aromatic raw materials has a value of 6.66 units pH (*Agastache foeniculum*) to 7.20 units pH (*Satureja hortensis*).

Aqueous-alcoholic infusions from vegetable raw materials and a volume fraction of ethanol of 40% have the value of regenerative capacity (recovery energy – RE) in the range from RE 100.0 mV (*Nepeta transcaucasica* Grossch) to RE 138.2 mV (*Ruta graveolens*). For the restaurant business in the manufacture of alcoholic beverages are promising aqueous-alcoholic infusions of *Ruta Graveolens* and *Nepeta transcaucasica* Grossch, which received increased antioxidant characteristics RE 138.2 mV and RE 100.0 mV, respectively, and positive sensory evaluation ($S.e.$) 9.57 and $S.e.$ 9.69 points.

The prescription composition of alcoholic beverages may include aqueous-alcoholic infusions with a mass fraction of extractives – up to 60 g/100 cm³ (liqueur).

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) [39, 40] was performed in the Pearson correlation matrix (Table 6).

Table 6

Marked correlations (r) are significant at $p < 0,05$; $N=9$

	t	pH	Eh_{min}	Eh_{act}	RE	$S.e.$
t	1,00	0,40	-0,40	0,48	-0,46	0,30
pH	0,39	1,00	-1,00	0,76	-0,95	-0,06
Eh_{min}	-0,39	-1,00	1,00	-0,76	0,95	0,06
Eh_{act}	0,48	0,80	-0,80	1,00	-0,93	0,01
RE	-0,46	-0,90	0,90	-0,93	1,00	0,03
$S.e.$	0,30	-0,10	0,10	0,01	0,03	1,00

where: t – temperature of infusion; pH – active acidity of the test solution; Eh_{min} – minimal theoretically expected meaning of RP ; Eh_{act} – actual measured RP ; RE – recovery energy; $S.e.$ – sensory evaluation

According to the obtained matrix 6*6, it was found that of the 6 indicators (t , pH , Eh_{min} , Eh_{act} , RE , $S.e.$), only 4 indicators are statistically significant. As a result of research it was found that physicochemical parameters (t , pH , Eh_{min} , Eh_{act} , RE) are statistically insignificant for sensory evaluation ($S.e.$), because the correlation coefficient is very weak ($r=0.0-0.3$). Also, a weak ($r=0.3-0.5$) and very weak ($r=0.0-0.3$) relationship is observed between temperature (t) and other physicochemical and sensory evaluation. The range of values with very high correlation ($r=0.9-1.0$) includes the following indicators: pH , Eh_{min} , Eh_{act} , RE .

Figure 8 shows the graphical dependence of pH on Eh_{min} . It was found that the pH is in the range of 6.66–7.96, and Eh_{min} 182.4–260.4 mV. According to the obtained equation, at a pH value of 7.00 Eh_{min} is 240 mV. When the pH value changes by 1 (pH 8.00), the Eh_{min} decreases by 60 mV (Eh_{min} 180 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} . Based on the research, it was found that the addition to the aqueous-alcoholic system with a weakly alkaline environment of vegetable spicy-aromatic raw materials, which leads to acidification and reduction of the pH level in the neutral environment (pH 6.66–7.20).

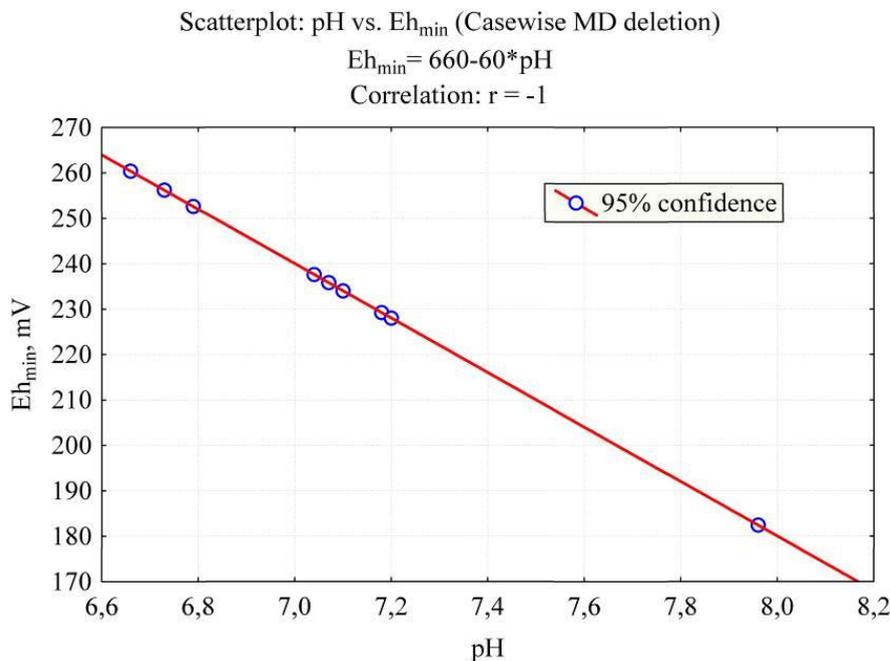


Figure 8. Dependence of pH level on the RP (Eh_{min})

Figures 9–13 show the graphical dependence of the pH level, Eh_{act} , Eh_{min} , RE .

It was found that Eh_{act} is in the range from 117 to 180 mV, and the pH is 6.66–7.96. At the value of Eh_{act} 120 mV, the pH level is 6.8. If you increase the pH to by one to 7.8 then the value of Eh_{act} will be 159 mV, i.e. Eh_{act} will increase by 39 mV. This is due to the fact that there is a very strong interdependence between the variables Eh_{act} and pH ($r=0.8$). As the pH value increases, the Eh_{act} index increases.

It was found that RE is in the range from 2.4 to 138.2 mV, and the pH is 6.66–7.96. When the value of RE 132 mV, the pH level is 6.8. If you increase the pH by one to 7.8, the value of RE will be 32 mV. Increasing the pH per unit from 6.8 to 7.8 leads to a decrease in RE by 100 mV. This is due to the fact that there is a very strong interdependence between the variables RE and pH ($r=-0.9$). As the pH value increases, the RE decreases.

Scatterplot: pH vs. $E_{h_{act}}$ (Casewise MD deletion)

$$E_{h_{act}} = -142,0 + 38,6 * pH$$

Correlation: $r = 0,8$

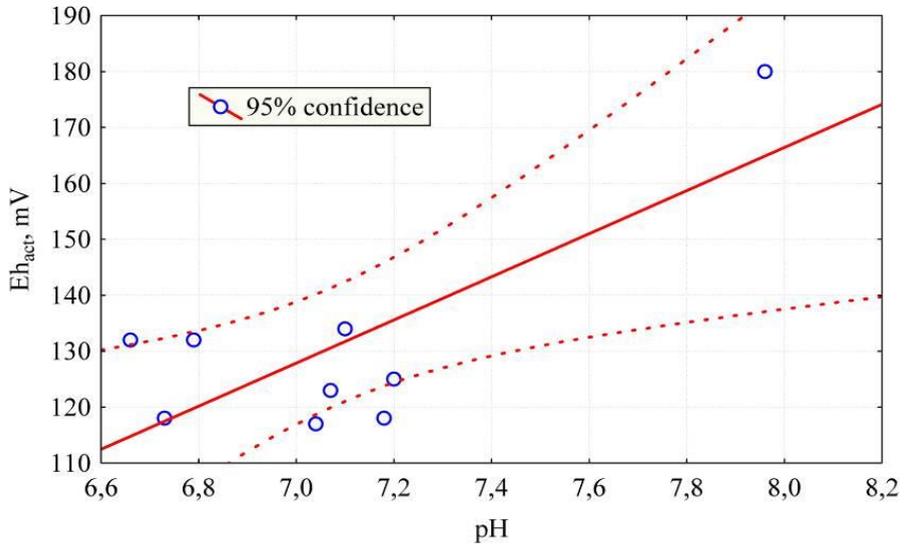


Figure 9. Dependence of pH level on the RP ($E_{h_{act}}$)

Scatterplot: pH vs. RE (Casewise MD deletion)

$$RE = 801,98 - 98,55 * pH$$

Correlation: $r = -0,9$

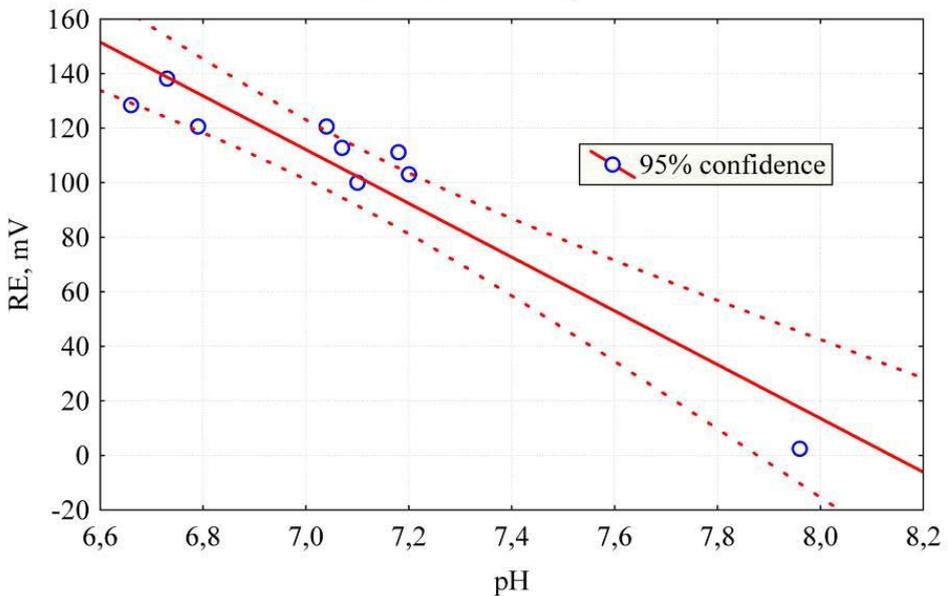


Figure 10. Dependence of pH level on reduction energy (RE)

Scatterplot: Eh_{min} vs. Eh_{act} (Casewise MD deletion)

$$Eh_{act} = 282,08 - 0,64 * Eh_{min}$$

Correlation: $r = -0,8$

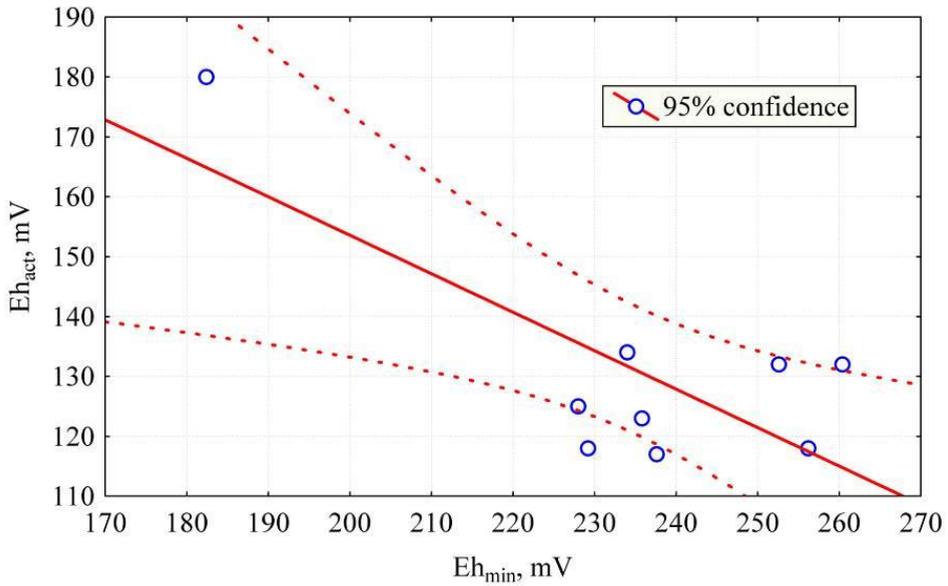


Figure 11. Dependence of $RP(Eh_{min})$ on $RP(Eh_{act})$

Scatterplot: Eh_{min} vs. RE (Casewise MD deletion)

$$RE = -282,1 + 1,6 * Eh_{min}$$

Correlation: $r = 0,9$

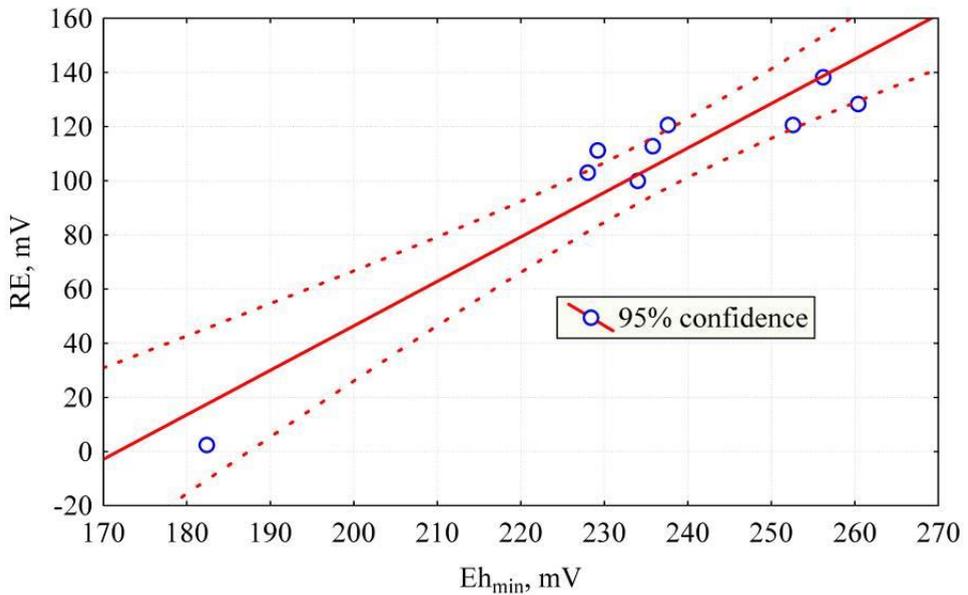


Figure 12. Dependence of $RP(Eh_{min})$ on reduction energy (RE)

Scatterplot: Eh_{act} vs. RE (Casewise MD deletion)

$$RE = 352,90 - 1,90 * Eh_{act}$$

Correlation: $r = -0,9$

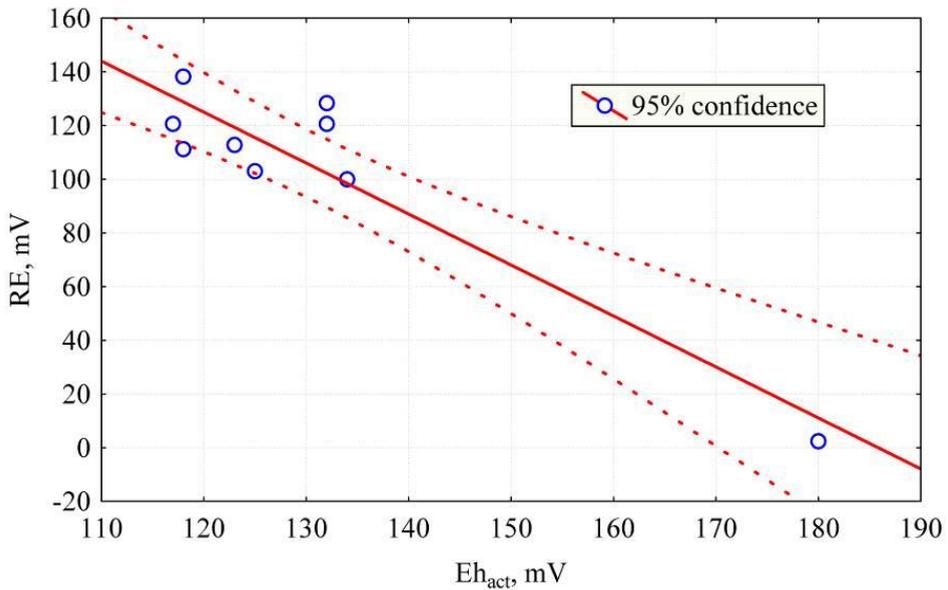


Figure 13. Dependence of $RP (Eh_{act})$ on reduction energy (RE)

The general graph of the three most correlation-significant physicochemical parameters is shown in Figure 14. In volumetric form, it is seen that some points (Eh_{act} , RE , Eh_{min}) 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.

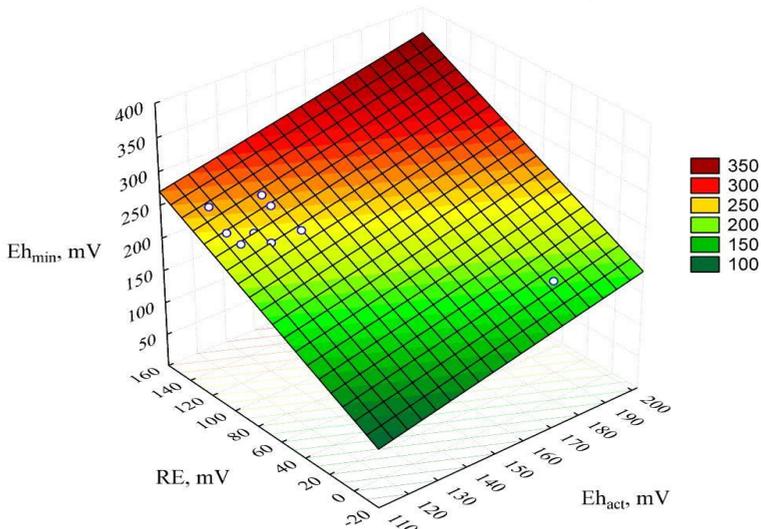


Figure 14. Response surface of $RP (Eh_{act})$ from reduction energy (RE) and $RP (Eh_{min})$

Figures 15-19 show graphs with histograms that show the frequency of variable values in individual intervals. The histogram visually represents the distribution of a continuous numerical variable, which measures the frequency of occurrence of similar values in the data set. The x-axis shows the numerical values, which are divided into ranges. Each range corresponds to a column of the histogram; the width of the column corresponds to the value of the interval, and the height is the number of elements in the data set, the values of which fall into this interval.

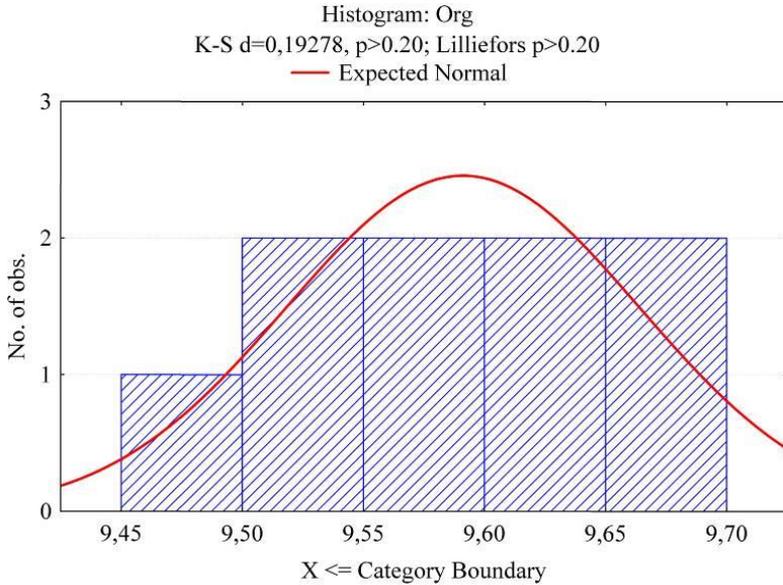


Figure 15. Histogram of the distribution of sensory evaluation (S.e.)

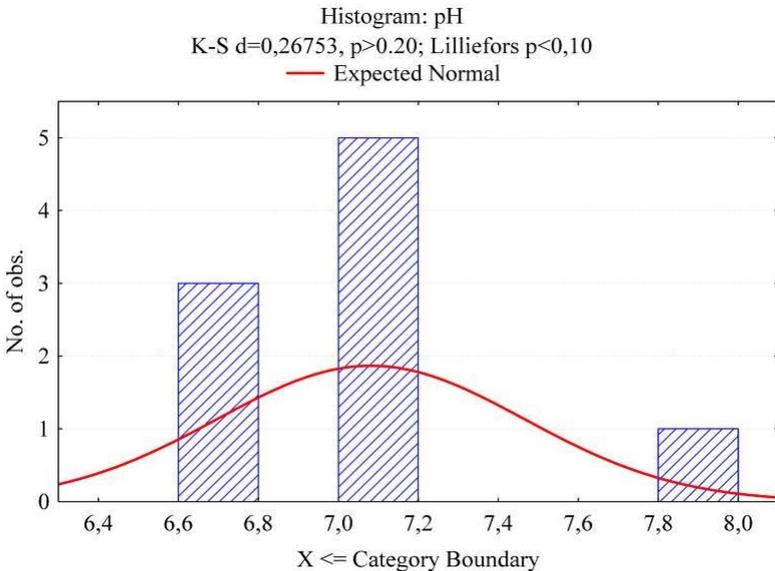


Figure 16. Histogram of the distribution of pH values

The histogram of the distribution of sensory evaluation is shown in Figure 15. Numerical values are divided into ranges with an interval of 0.5, starting from 9.45 to 9.70 points. Only 5 ranges and the same number of columns. The maximum frequency is typical for 4 ranges in the range 9.50–9.70 points – 8 values of the variable. The lowest frequency has the range 9.45–9.50 points, which got 1 value of the variable.

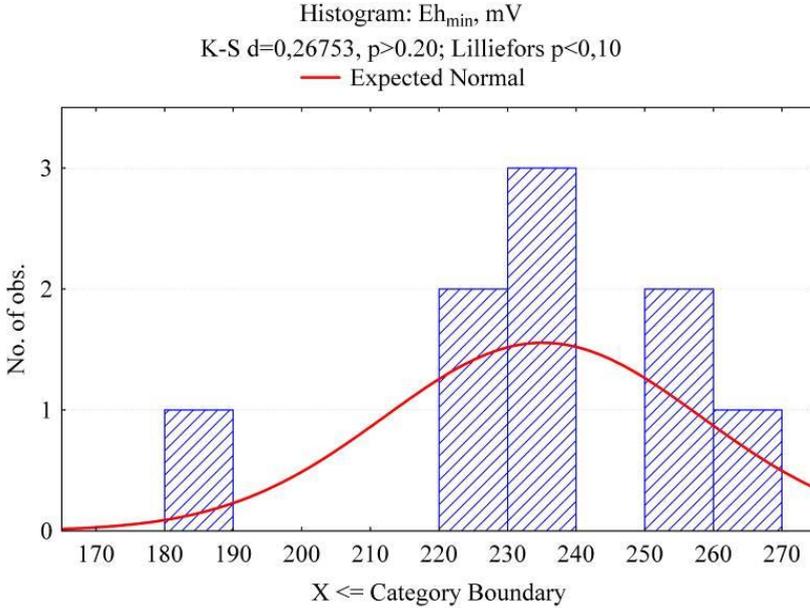


Figure 17. Histogram of the distribution of values of the level of RP (Eh_{min})

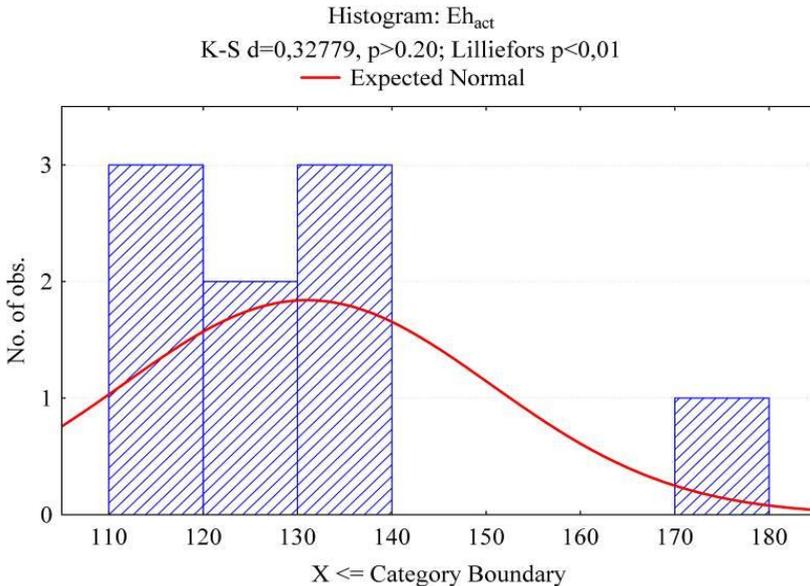


Figure 18. Histogram of the distribution of values of the level of RP (Eh_{act})

Figure 16 shows the distribution of pH values, the range of which is divided into 3 columns. It is established that 9 data elements lie in the range of pH values 6.6–8.0. The highest frequency 5 is the range of pH values 7.0–7.2, 3 – in the range of pH values 6.6–6.8, and only 1 – in the range 7.8–8.0, which is the lowest frequency.

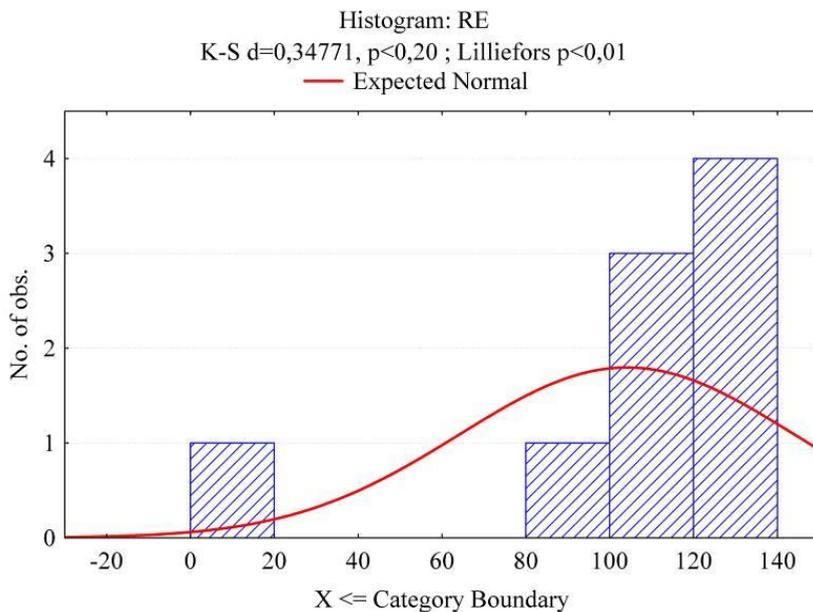


Figure 19. Histogram of the distribution of recovery energy values (RE)

Figure 17 shows the histogram of RP (Eh_{min}). The x-axis is divided into 5 ranges ranging from 180 to 270 mV. According to the values of the elements in the data set, only 5 columns. The maximum frequency is typical for the range 230–240 mV, which includes 3 elements. The lowest frequency is characteristic for the ranges 180–190 mV, 260–270 mV, which includes 1 element.

The value of the histogram (Eh_{act}) (Figure 18) is divided into 4 ranges, starting with 110 and ending with 180 mV. The maximum repetition rate is typical for the range 110–120 mV and 130–140 mV, each includes 3 values. The lowest frequency of the ranges is 170–180 mV, which includes 1 element.

Figure 19 shows a histogram of RE , which includes 4 ranges starting from 0 to 140 mV. The maximum frequency, which consists of 4 elements, belongs to the range 120–140 mV, and the lowest 0–20 mV and 80–100 mV, which include 1 element.

Histograms allow you to develop statistics on the frequency of values in a certain range. They are a generalized view of the data obtained during sensory evaluation and physicochemical values (Shendrik et al., 2019) [40].

Based on mathematical and statistical analysis, it was found that physicochemical parameters (pH , Eh_{min} , Eh_{act} , RE) are statistically insignificant for sensory evaluation ($S.e.$) and infusion temperature (t). The range of values with very high correlation ($r=0.9-1.0$) includes the following indicators: pH , Eh_{min} , Eh_{act} , RE .

Development of recipes of alcoholic beverages

On the basis of the obtained results, it was established that the maximum values of *RP* have extracts of *Ruta graveolens* and *Nepeta transcaucasica* Grossch. These extracts were used in the preparation of cocktails, the recipes of which are presented in Table 7-8.

Table 7

Composition of the cocktail «Mint mulled wine»

Ingredients	Content, %
Red wine	62.65
Extract of <i>Nepeta transcaucasica</i> Grossch	25.0
Sugar	12.0
Nutmeg, cloves, cinnamon, allspice	0.35

Table 8

Composition of the cocktail «Pomegranate grog»

Ingredients	Content, %
Extract of <i>Ruta graveolens</i>	27.0
Ginger	0.5
Grenadine	8.5
Lemon fresh	14.0
Black tea	50.0

The data obtained are correlated with the basic scientific concepts which are displayed in the works (Kamdem et al., 2013; Frolova et al., 2019; Gerolis et al., 2017; Imark et al., 2000; Pyrzynska, Sentkowska, 2019; Wong et al., 2020; Sentkowska, Pyrzynska, 2018; Siddiqui et al., 2018; Steenkamp et al., 2004; Ruiz-Ruiz et al., 2020; Naithani et al., 2006; Buglass et al., 2012; Grunert et al., 2018; Gullón et al., 2018; Gulua et al., 2018; Joubert, Beer, 2012; Silka et al., 2016; Naumenko et al., 2015; Frolova, Korablova, 2016) [10–18, 25, 26, 30–34, 43–45], regarding the processes of extracting of plant materials.

Improvement of the technology of alcoholic beverages (Andreou et al., 2018; Chandrasekara, Shahidi, 2018; Iannitti, Palmieri, 2009; Halliwell, Gutteridge, 1990; Kawa-Rygielska et al., 2019; Fotakis et al., 2016; Vergun et al., 2018; Vergun et al., 2019; Kurylo et al., 2018) [4–9, 27–29] is due to the addition of spicy-aromatic aqueous-alcoholic infusions. It allows to increase the antioxidant properties of the product (Breiter et al., 2011; Dube et al., 2017; Keating et al., 2014; Oh et al., 2013; Herrera et al., 2018; Humia et al., 2020; Vergun et al., 2018; Vergun et al., 2019; Kurylo et al., 2018) [19–24, 27–29], will help to increase the immunity of the human body, improve the metabolism, positively affect the cardiovascular system, in addition it increases the consumer properties and will allow to reduce the cost of the finished product.

Conclusions

1. It is established that one of the promising ways of forming consumer properties and expanding the range of alcoholic products is the use of new types of spicy-aromatic plants, which include biologically active substances. Such substances improve the sensory evaluation of beverages, contribute to the promotion of human health (antioxidant effects, enhancing redox reactions).
2. Experimental studies show that all aqueous-alcoholic infusions of aromatic origin contain antioxidant systems. It was found that the recovery value of all the tested extracts is positive and ranges from 100.0 to 138.2 mV.
3. Histograms allow you to develop statistics on the frequency of values in a certain range. They are a generalized view of the data obtained during sensory evaluation and physicochemical values.
4. Based on mathematical and statistical analysis, it was found that the infusion temperature (t) has a statistically insignificant effect on physicochemical parameters (pH , Eh_{min} , Eh_{act} , RE), which have a statistically insignificant effect on sensory evaluation (*S.e.*). The range of values with very high correlation ($r=0.9-1.0$) includes the following indicators: pH , Eh_{min} , Eh_{act} , RE .
5. Improvement of the technology of alcoholic cocktails by adding spicy-aromatic aqueous-alcoholic infusions allows to increase the redox properties of the product, increases consumer properties and reduces the cost of the finished product.

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