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Investigation of the yield of biologically active substances during the ultrasound and electro-discharge extraction of medicinal herbs of the foothills of the North Caucasus

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ABSTRACT

Biologically active components are present in plants in small quantities. There are many different extraction methods, which can be used for their extraction. In this scientific work, extracts of three plants (common origanum, peppermint and garden sage) were prepared in three different ways: water extraction, ultrasound extraction and electro-discharge extraction. The dynamics of saturation of extracts with flavonoids, essential oils and organic acids for each case were studied within 48 hours after the experiment's start. The conducted studies have confirmed the effectiveness of electro-discharge extraction in comparison with ultrasound and in comparison with water extraction. Forty-eight hours after the start of the experiment, 7-15% more organic acids, flavonoids and essential oils were observed in extracts of the studied plants obtained after electro-discharge treatment than in water extracts. A similar dynamic can be traced in the assessment of all indicators. At the same time, 80% readiness of extracts in the case of electro-discharge treatment was observed already 30 minutes after the start of the experiment. Similar indicators (80% of the maximum) were achieved after 24 hours of water extraction and after 2 hours with ultrasound treatment. Thus, the electro-discharge treatment allows you to obtain higher-quality and more enriched active substance extracts in a much shorter time. At the same time, electro-discharge treatment has a significant list of disadvantages described in detail in this article.

Keywords: herbal extract, water extract, ultrasound extract, electric pulse extraction, medicinal herbs

INTRODUCTION

Plant-based ingredients are frequently used in the food industry to give foods distinctive flavors and aromas. For example, lemongrass, ginseng, green tea, and eleutherococcus are often used in the production of energy drinks; bay leaf, onion, pepper, parsley, cumin, dill, horseradish, garlic are used in the production of sauces, sausages, crackers; anise, vanilla, peppermint, tarragon, etc. are used in the confectionery and alcohol industry **[1]**, **[2]**, **[3]**, **[4]**. Many biologically active components are present in plants in small quantities, so there is a need for their isolation and/or concentration. One of the ways to solve this problem is the extraction process **[5]**, **[6]**. Extraction is a method that allows you to extract flavoring components from vegetable raw materials. Extracts are concentrated products of liquid (liquid extracts and tinctures), soft (thick extracts) or solid (dry extracts) consistency obtained from vegetable raw materials or animal materials **[7]**, **[8]**. Currently, when obtaining plant extracts, the technology of long–term infusion of raw materials with an extractant is widely used, as which in most cases, alcohol solutions with a mass fraction of alcohol of 40-80% are used. Water infusions of vegetable raw materials are also made by pouring boiling water and holding it at a temperature of 70-80 °C for 4-6 hours **[9]**. This method of processing plant raw materials does not allow the maximum use of extractive substances. It obtains extracts enriched with substances of carbohydrate and protein nature, micro- and macroelements, flavouring and tannins, vitamins, organic acids, glycosides and other compounds. Therefore, their selective ability must be considered when choosing the extraction method and the extractant **[10]**. In the food industry, water, alcohol, hexane, acetone, and liquefied carbon dioxide are usually used as extractants **[11]**. The extractant plays a significant role in the extraction of biologically active substances. It must have the ability to penetrate through the cell walls and selectively dissolve biologically active substances inside the cell, after which the latter must pass through various hard shells and go beyond the plant material. In addition, it should have low toxicity (the use of dichloroethane, benzene, pyridine, etc. is unacceptable), dissolve essential oils and oleoresins, have a low boiling point and be removed from the extract as wholly as possible by distillation **[12]**, **[13]**. The raw materials for obtaining extracts are fresh or dried parts of plants: bark, roots, stems, wood, leaves, petals, inflorescences, and seeds **[14]**. Often extracts from the same plant are completely different in composition, action and aroma.

As a rule, the diffusion rate in the solid phase limits the extraction of biologically active substances (BAS) from natural materials of plant origin. Therefore, intensifying the processes of obtaining extracts for food production is of great practical importance. This is because, firstly, the extraction processes are lengthy; secondly, the stability and organoleptic characteristics of the finished products significantly depend on the quality of the extracts. This fact makes it necessary to research the development and improvement of technology for obtaining extracts from plant raw materials, providing for the directed regulation of their properties.

Currently, there is extensive experience in the introduction of new methods that intensify mass transfer in a solid-liquid system, which are based on methods for measuring vibrations, pulsations or vibrations of various amplitudes, frequencies and intensities **[15]**, **[16]**, **[17]**.

The ultrasound extraction method is often used in the food industry. Regulation of the BAS extraction process using ultrasound is of interest for scientific research concerning abnormal processes occurring during ultrasound water treatment. The main advantage of ultrasound technology is the impact of specific factors inherent in ultrasonic vibrations: the cavitation effect, the formation of micro-flows and the effect on the diffusion permeability of the tissue of the extracted material. In this regard, using ultrasound to obtain extracts is of great interest **[18]**, **[19]**.

Along with many methods of intensifying the BAS extraction process, electro-discharge treatment is promising. The high-voltage electro-discharge treatment is based on the phenomenon of the electrohydraulic effect. The principle of the appearance of the electrohydraulic effect is the phenomenon of a sharp increase in the hydraulic and hydrodynamic effects and the amplitude of the shock action during the implementation of a pulsed electric discharge in an ion-conducting liquid, provided that the pulse duration is maximally shortened, the pulse front is as steep as possible, and the pulse shape is close to the aperiodic **[20]**. The main operating factors of the electrohydraulic effect are:

– high and ultra-high pulsed hydraulic pressures, leading to the appearance of shock waves with sonic and supersonic speeds;

– significant pulsed movements of fluid volumes, occurring at speeds reaching hundreds of meters per second;

– powerful pulsed cavitation processes capable of covering relatively large volumes of liquid **[21]**;

– infra- and ultrasonic radiation; mechanical resonant phenomena with amplitudes that allow mutual exfoliation of multicomponent solids from each other;

– powerful electromagnetic fields (tens of thousands of oersted);

– intense pulsed light, thermal, ultraviolet radiation;

– multiple ionization of compounds and elements contained in the liquid **[22]**.

Electric discharge technology with the use of rectangular pulses of nanosecond duration reduces the processing time of raw materials from 12-36 hours to 10-15 minutes, and has a number of additional advantages, such as:

– disinfection of the extract during treatment with high-voltage pulses **[23]**;

– the possibility of using non-toxic extractants due to the high extraction efficiency with water, etc. **[24]**.

Thus, this work aimed to study the effectiveness of the ultrasonic and electric pulse method of extracting medicinal herbs from the Foothills of the North Caucasus.

Scientific Hypothesis

The method of extraction using ultrasound and electro-discharge treatment will allow for obtaining high-quality extracts in a shorter time than the classical method of obtaining water extracts. And at the same time, such extracts will be more enriched with useful elements than water extracts.

MATERIAL AND METHODOLOGY

Samples

Extracts from medicinal herbs of the Foothills of the North Caucasus: garden sage (*Salvia officinalis*), common origanum (*Origanum vulgare*)and peppermint (*Méntha piperíta*) were prepared with conventioanls and intense methods and used as experimental samples. Garden sage, common origanum and peppermint were collected in Stavropol Region near the Strizhament mountain in July-August 2021.

Chemicals

We used reagents of recognized analytical purity and distilled water. The following chemicals were used in work: Ethanol, Sodium hydroxide, Sodium carbonate, Aluminum chloride, and Ascorbic acid. All chemicals above were purchased by LenReactive LLC (Sants Petersburg, Russia) and were of analytical grade quality.

Animals and Biological Material

The following herb collections were used as objects of research: common origanum (according to GOST 21908 – 76), peppermint (according to GOST 21908 – 93), garden sage (according to GOST 1994 – 43) **[25]**, **[26]**, **[27]**. The content of some micro- and macroelements contained in these plants is presented in Table 1.

Common origanum has soothing, anti-inflammatory, antibacterial, analgesic, diuretic, anthelmintic, and insecticidal properties. The content of essential oil is not less than 0.8%; humidity is not more than 14%; total ash is not more than 12%; blackened and browned leaves are not more than 5%; other parts of the plant (flowers and pieces of stems) are not more than 13%; particles passing through a sieve with holes of 0.5 mm in size are not more than 10%; organic impurity not more than 3%; mineral impurity not more than 0.5%.

Peppermint is a perennial herbaceous plant with a height of 25-60 cm. The stem and the entire plant are bristly-hairy or smooth. Essential oil not less than 1%; humidity, not more than 14%; total ash not more than 14%; ash insoluble in 10% hydrochloric acid solution, not more than 6%; blackened leaves not more than 6%, stems not more than 10%; particles passing through a sieve with 0.5 mm holes, not more than 8%; organic impurity not more than 3%; mineral impurity not more than 1%.

Garden sage is used not only in cooking, but also in medicine. It helps to normalize the work of the cardiovascular system, reduce blood pressure, and improve cerebral circulation. Garden sage contains up to 2.5% essential oil, 4% condensed tannins, ursolic and oleanolic acids, phenolic carboxylic acids, vitamins, macro- and microelements, diterpenes, bitter substances, 5-6% resinous substances, flavonoids, coumarin esculetin, etc.

Table 1 The content of some macro- and microelements in the plant raw materials used, mg.

Chemical element	Common origanum	Peppermint	Garden sage
K	19.80	569	22.90
Ca	12.40	243	40.90
Mg	2.10	80	9.20
Fe	0.63	5.08	0.80
Mn	0.12	1.176	99.20
Cu	0.49	329	15.50
Zn	0.34	1.11	97.40

Instruments

The amount of flavonoids in plant raw materials was determined photometrically after reacting with aluminium chloride on a photocolorimeter KFK-3 (ProfMT, St. Petersburg, Russia). Studies of the kinetics of accumulation of biologically active substances were carried out on the Bruker MaXis Impact mass spectrometer using Target Analysis software (Bruker, Belgium)

Laboratory Methods

During the experimental studies, the following methods were used to determine individual analytes:

Definitions of extractive substances: 1 g of raw materials, crushed and sifted through a sieve with holes with a diameter of 1 mm, is placed in a conical flask, and 50 ml of the solvent specified in the standard technical documentation for this type of raw material is poured. The flask is closed with a stopper, weighed with an error of no more than 0.01 g and left for 1 h. Then the flask is connected to a reverse refrigerator, heated to a boil, and a weak liquid boiling is maintained for 2 h. After cooling, the flask with the contents is again closed with the same stopper, and weighed and the mass loss is supplemented with the same solvent. The contents are thoroughly shaken and filtered through a dry paper filter into a dry flask with a capacity of 150-200 ml. 25 ml of filtrate is transferred to a porcelain cup with a diameter of 7-9 cm, pre-dried at 100-105 °C to a constant weight and weighed on analytical scales, evaporated dry in a water bath, dried at 100-105 °C for 3 hours, then cooled in desiccator and quickly weighed **[28]**.

The percentage of extractive substances (x) in absolutely dry raw materials is calculated by the formula (1):

$$x = \frac{m\ 200 \times 100}{m_1 \times (100 - w)} \qquad (1)$$

Where:
m – is the mass of the dry residue in the cup, g; m_1 – is the mass of raw materials, g; w – is the loss of raw materials during drying, %.

Determination of flavonoid content in raw materials: The analytical sample of raw materials is crushed to the particle size, passing through a sieve with holes of 1 mm. The exact weight (1 g of raw materials) is placed in a flask with a capacity of 100 ml, 30 ml of 70% alcohol is added, attached to a reverse refrigerator and heated in a boiling water bath for 30 minutes. After cooling to room temperature, the contents are filtered through a paper filter into a 100 ml volumetric flask (for complete extraction of flavonoids, extraction is repeated twice by the above method, and the extracts obtained are filtered into the same volumetric flask through the same filter). The filter is washed off with 70% alcohol, and the filtrate volume is brought to the mark with the same alcohol. The resulting solution will be called "solution A". 4 ml of "solution A" is placed in a measuring flask with a capacity of 25 ml, 2 ml of a 2% solution of aluminium chloride in 95% alcohol is added, and the volume is brought to the mark with 95% alcohol. After 20 minutes, the optical density is measured on a photocolorimeter KFK-3 (ProfMT, St. Petersburg, Russia) at a wavelength of 410 nm in a cuvette with a layer thickness of 10 mm **[29]**.

Determination of organic acid content: The total content of organic acids is determined by titration using indicators. An aliquot of the infusion equal to 100 ml is placed in a 250 ml flask, and 100 ml of distilled water is added and titrated with a 0.1 M sodium hydroxide solution in the presence of phenolphthalein and methylene blue indicators until a purple-red colour appears in the foam **[30]**.

Mass spectrometry: The elemental content of organic compounds in the model samples was determined by mass spectrometry with inductively coupled argon plasma on a quadrupole mass spectrometer Bruker MaXis Impact with Target Analysis software (Bruker, Belgium). The detection limit in a water solution is 1 mcg/l. Studies of the kinetics of the accumulation of biologically active substances were carried out on the Bruker MaXis Impact apparatus. Bruker MaXis Impact is a device designed for mass spectrometric analysis. The device detects and identifies known compounds, their metabolites, and unknown compounds in a wide range of masses from 20 to 40,000 Da (drugs, pesticides, etc.).

The content of essential oils: The content of essential oils was carried out by distillation from vegetable raw materials with water vapour of essential oil and subsequent measurement of its volume according to GOST 24027.2-80 **[31]**.

Description of the Experiment

Sample preparation: Medicinal herbs growing in the North Caucasus were selected as the objects of the study: garden sage (*Salvia officinalis*), common origanum (*Origanum vulgare*), peppermint (*Méntha piperíta*).

Following the technical requirements, the feedstock was dried to an air-dry state, then crushed and divided into separate fractions with a particle size of 5.0 mm. The samples of various fractions were extracted with water.

It should be noted that an increase in the temperature of the extractant is undesirable for essential oil raw materials since essential oils are largely lost when heated. An increase in temperature is advisable when extracting from roots, rhizomes, bark and leathery leaves. Hot water, in this case, contributes to a better separation of tissues and rupture of cell walls, thereby accelerating the course of the diffusion process. The production of acidified water extracts was carried out using both traditional and innovative methods. Traditional methods widely used in the production of extracts are the method of water extraction and ultrasound treatment. Obtaining a water extract using the method of water extraction was carried out as follows: selection and preparation of raw materials (degree of grinding 5 mm) was carried out, soaking in warm water at t = 40 °C for 15 minutes, then heating in a water bath to a temperature of t = 60 °C for two hours, then cooling and infusing. By ultrasonic treatment, the water extract was obtained as follows: the selection and preparation of raw materials was carried out (the degree of grinding is 5 mm), soaking in warm water at t = 40 °C for 15 minutes, ultrasound treatment for 30 minutes, then infusion. Extraction using high-voltage electro-discharge treatment was carried out as follows: selection and preparation of raw materials were carried out (degree of grinding 5 mm), soaking in warm water at t = 40 °C for 15 minutes, treatment for 10 minutes (360 discharges, 10 kV, 0.01 microfarads), then infusion.

Number of samples analyzed: 3

Number of repeated analyses: 3

Number of experiment replication: 1

Design of the experiment: The scheme of the experiment is shown in Figure 1.

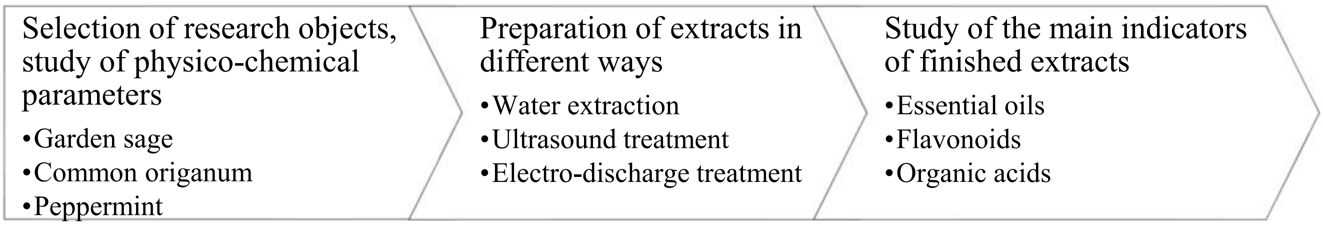

Figure 1 The scheme of the experiment.

Statistical Analysis

Statistical processing of experimental data. The obtained results were processed using the statistical package PASW Statistics 18, version 18.0.0 (SPSS Inc., USA). Verifying the normality of the distribution of signs was carried out using the Kolmogorov-Smirnov criteria. The critical significance level when testing statistical hypotheses in the study were assumed to be 0.05. The organic compounds' elemental content results were processed using the Target Analysis software package.

RESULTS AND DISCUSSION

On the first stage, after the extraction processes, we could observe the differences between groups in color (Figure 2). As can be seen on the example of Common origanum extracts, electro-discharge treatment caused the most intense colorization of the water during extraction. However, to make an objective conclusion we carried out complex experimental research.

Figure 2 Aqueous extracts of Common origanum obtained with water extraction, ultrasound (US), and electro-discharge (ED) treatment.

To obtain a complete picture of the effectiveness of various extraction methods (water extraction, ultrasound treatment and electro-discharge treatment), we analyzed the content of organic acids, essential oils and flavonoids in extracts at various time intervals:

– 15 minutes after the start of the experiment (the end of the soaking stage),
– 30 minutes after (the end of the electric discharge treatment),
– after 2 hours (end of ultrasound treatment),
– after 8 hours (intermediate value),
– after 24 hours (intermediate value),
– after 48 hours (the end of the experiment).

The results of the research are presented in Figures 3, 4 and 5.

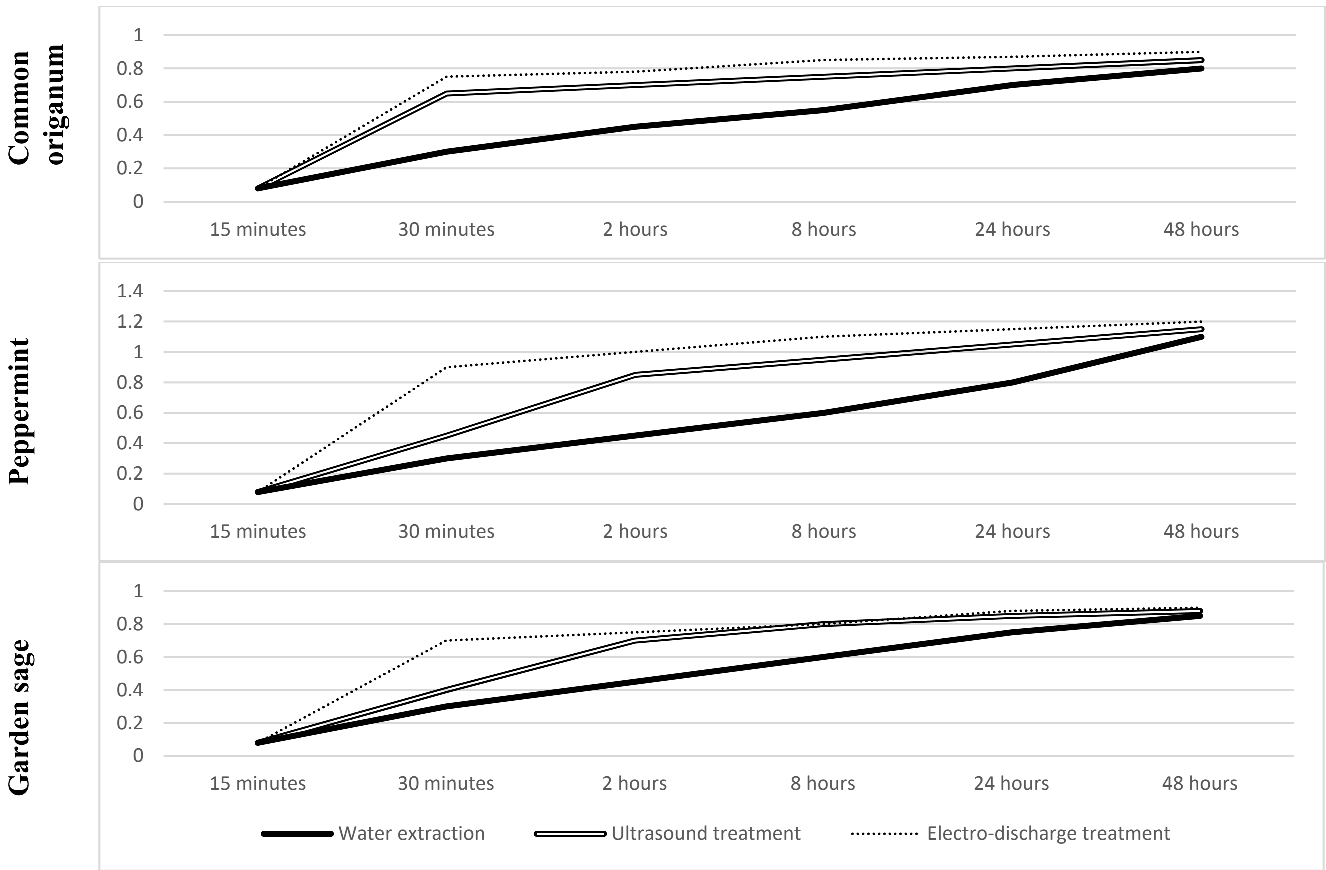

Figure 3 Essential oil content (%) in Common origanum, Peppermint and Garden sage.

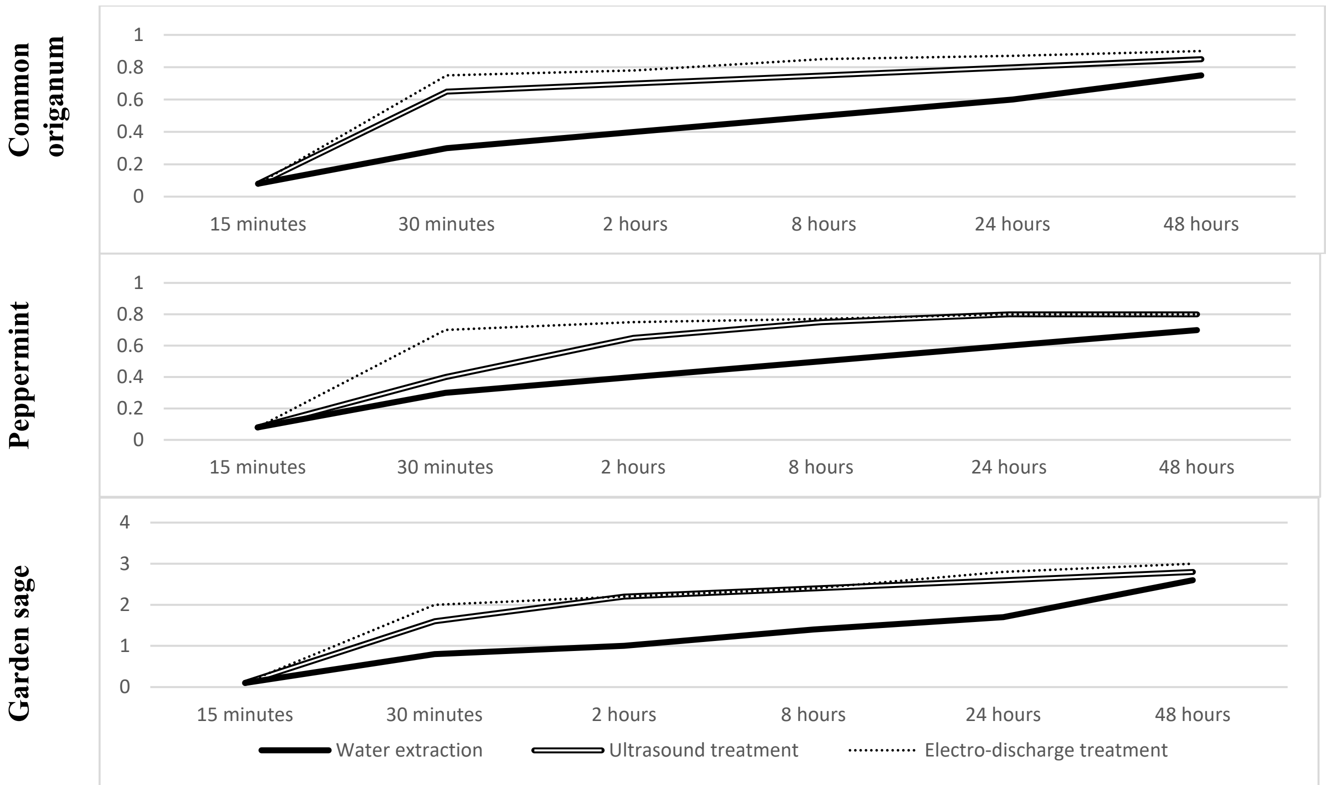

Figure 4 Flavonoid content (%) in Common origanum, Peppermint and Garden sage.

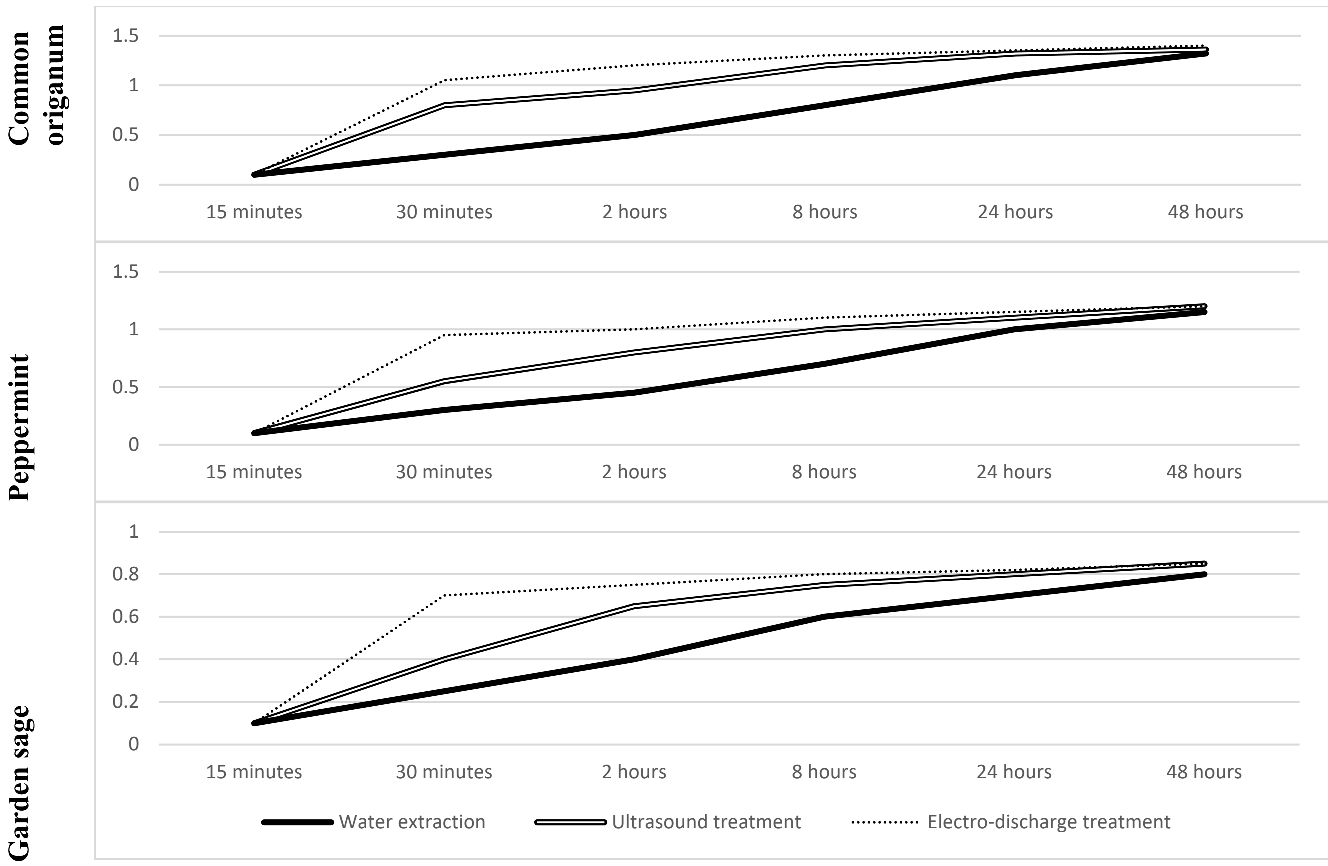

Figure 5 Organic acids content % ml of 0.1n NaOH in Common origanum, Peppermint and Garden sage.

The results of the conducted studies show a unified picture of the transition of useful substances into liquid extracts. So, after 48 hours, the maximum content of essential oils, flavonoids and organic acids is reached, while the indicators of water extracts are, on average, 7 – 10% lower than extracts obtained by electro-discharge and ultrasound treatments. At the same time, 80% of the maximum value is reached after 24 hours in the case of water extraction, after 2 hours with ultrasound treatment and after 30 minutes with electro-discharge treatment. Similar dynamics can be traced in the evaluation of all indicators.

The obtained extracts are largely enriched with useful micro- and macroelements and vitamins. They are promising to increase the body's resistance to adverse environmental factors **[32]**. In addition, the obtained extracts have a pleasant, harmonious taste and aroma, which means they can produce various food products **[33]**. Using modern technologies, such as ultrasound and electro-discharge extraction and producing extracts and biologically active additives will allow for more productive use of natural plant resources **[34]**. When extracted by different methods, the accumulation rate of organic acids in extracts varies **[35]**. This is explained by the fact that under the intense influence of ultrasound or electrical discharges on solid particles, strong turbulent currents and hydrodynamic micro-flows occur, contributing to substance mass transfer and dissolution **[36]**. Interestingly, these phenomena are observed both in the surrounding liquid and directly inside solid particles **[37]**. In electro-discharge treatment, a large amount of energy is accumulated in local areas, and then its instant release. These processes make it possible to intensify various chemical and technological processes. In particular, there is the appearance, development and explosion of cavitation regions, additional grinding of solid fractions, and the rupture of sorption bonds **[38]**. As confirmed by the studies of other authors, during electro-discharge treatment, water's redox potential may change, and various physical and chemical changes in the processed raw materials may occur **[39]**. Ultraviolet radiation that occurs during electro-discharge treatment has a detrimental effect on the microflora of the treated liquid, which, ultimately, allows to increase in the shelf life of the irradiated extract **[40]**. Table 2 shows the study results of dry substances in ready-made extracts of common origanum, peppermint and garden sage, depending on the extraction method. The maximum values are presented 48 hours after the start of extraction.

Table 2 Dry matter content in prepared extracts.

Method of extract production	Common origanum, %	Peppermint, %	Garden sage, %
Water extraction	2.87 ±0.15	2.95 ±0.15	4.25 ±0.22
Ultrasound treatment	3.07 ±0.16	3.15 ±0.16	4.53 ±0.23
Electro-discharge treatment	3.3 ±0.16	3.2 ±0.16	4.75 ±0.24

The following unique phenomena occurring during electro-discharge treatment of liquid have been experimentally identified and confirmed:

− Reduction of microbiological contamination of the liquid **[39]**;

− Softening of water, precipitation of calcium and magnesium salts **[39]**, **[40]**;

− Reduction of suspended solids concentration **[41]**;

− The transition of the value of the redox potential of water to a stable negative range of values **[42]**;

− Change of pH values towards the neutrality of the medium **[43]**.

Preparation of the extract using electro-discharge treatment allows you to obtain a high-quality extract within 30 minutes after the start of the experiment (15 minutes of soaking, 10 minutes of processing, and cooling). Ultrasonic exposure makes it possible to obtain a high-quality extract 2 hours after the start of the experiment (15 minutes of soaking, 30 minutes of processing, cooling and infusing). Thus, it can be concluded that the efficiency of ultrasonic and electric discharge extraction is unambiguous compared to the traditional technology of preparing an aqueous extract **[44]**.

The next stage of the study was a comparative analysis of the kinetics of the accumulation of biologically active substances in ready-made common origanum extracts (Table 3). The highest accumulation of extractive substances is observed in the third sample obtained using electric discharge technology. The lowest content is observed in the first sample obtained by classical extraction with an aqueous extract. The obtained conclusions are also confirmed by the results of other studies **[45]**.

Despite the obvious advantage of electro-discharge treatment over ultrasound, a number of disadvantages of this technology are also obvious. In particular, the energy costs for conducting experiments with electro-discharge treatment turned out to be almost 7 times higher than for ultrasonic treatment **[46]**. In addition, the electro-discharge treatment's light and sound accompaniment require a specially equipped room with high sound insulation properties **[46]**. The costs for the purchase and maintenance of electro-discharge equipment are 12-18 times higher than similar costs for the maintenance of an ultrasonic radiator **[47]**. In addition, electric discharge treatment requires a careful approach to choose the treatment mode due to the significant heating of the liquid **[48]**. And this means that food processing enterprises using electro-discharge equipment must have a technologist-adjuster in the staff of the main employees.

Table 3 Results of the study of the kinetics of accumulation of biologically active substances (*p* <0.05 for all groups).

No.	Characteristics of the main peaks		Relative intensity, %			Approximate content, grams per 100 g of sample		
	Weight	Gross formula	Water extraction	US treatment	ED treatment	Water extraction	US treatment	ED treatment
1	445.099	C19H17N409	8.84	8.85	35.72	0.95	1.43	2.11
2	383.1125	C21H1907	8.06	9.77	15.8	0.89	1.58	0.93
3	365.1033	C22H13N402	11.79	14.96	25.98	1.24	2.42	1.54
4	219.0264	C9H805Na	100	100	86.6	9.85	16.20	5.124
5	215.0162	C6H807Na	11	20	100	1.45	3.24	5.91
6	203.052	C6H1206Na	81.72	7.61	41.49	7.42	1.23	2.45
7	171.0992	C7H1603Na	13.35	9.6	1	1.21	1.5	0.06
8	156.042	C8H7NONa	12.17	5.84	5.41	1.14	0.95	0.32
9	140.0706	C7H10N02	13.11	9.31	14.32	1.23	1.51	0.85
10	118.0863	C5H12N02	14.31	9.41	36.29	1.22	1.52	2.15
11	104.107	C5H14NO	77.31	66.15	63.2	7.16	10.72	3.74

So, when using electro-discharge equipment, a well-chosen liquid treatment mode is particularly important, in which the environment will not be overheated **[49]**. It is known that an increase in temperature above 60°C is undesirable for aqueous plant extracts **[50]**. First, this is explained by the irreversible decomposition of biologically active substances that are part of extractive substances **[51]**. In addition, a significant part of essential oils is lost when heated **[52]**. It is known that the content of essential oils provides the finished extracts with antispasmodic, antifungal, antiviral, sedative, wound healing, toning, relaxing, anti-stress, soothing, hypo- or hypertensive effects **[53]**. In addition, with significant heating, partial gelatinization of starch, and peptization of substances occurs **[54]**. Starch gelatinization is breaking the intermolecular bonds of starch molecules in the presence of water and heat, which allows the sites of hydrogen bonds to attract more water. In this case, starch granules are irreversibly dissolved in water. Water acts as a plasticizer **[55]**. The consistency of the extracts, in this case, becomes thicker and slimier and further work with them becomes much more difficult **[56]**.

CONCLUSION

Intensive exposure to ultrasound or electrical discharges on solid particles in a liquid leads to strong turbulent currents and hydrodynamic micro-flows promoting mass transfer and substance dissolution. As a result, intensive mixing of elements is achieved both in the total volume of the liquid and inside individual cells. Ultimately, this leads to an increase in the internal diffusion coefficient. The conducted studies have confirmed the effectiveness of electro-discharge extraction in comparison with ultrasound and comparison with water extraction. 48 hours after the start of the experiment, 7-15% more organic acids, flavonoids and essential oils were observed in extracts of the studied plants obtained after electro-discharge treatment than in water extracts. A similar dynamic can be traced in the assessment of all indicators. At the same time, 80% readiness of extracts in the case of electro-discharge treatment was observed already 30 minutes after the start of the experiment. Similar indicators (80% of the maximum) were achieved after 24 hours of water extraction and after 2 hours with ultrasound treatment. Thus, the electro-discharge treatment method proposed for extraction accelerates the time of obtaining the extract by 4 times compared to ultrasound. The dry matter content in the finished extracts also varied significantly (p <0.05). The finished extract of Common origanum as a result of electro-discharge treatment contained 3.3% of essential substances (ultrasound treatment – 3.07%, water extraction – 2.87%). As a result of electro-discharge treatment, Peppermint extract contained 3.2% of essential substances (ultrasound treatment – 3.15%, water extract – 2.95%). As a result of electro-discharge treatment, garden sage extract contained 4.75% of essential substances (ultrasound treatment – 4.53%, water extract – 4.25%). In addition to the high production speed of finished extracts and the higher quality of finished extracts, electro-discharge treatment has a detrimental effect on the microflora of the treated liquid. This ultimately allows you to increase the shelf life of the irradiated extract. The obvious drawbacks of electro-discharge treatment include increased energy consumption, high noise level, and the need to select the treatment mode that prevents excessive liquid overheating carefully.

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