International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-1, October, 2019

The Efficiency of Extracting Biologically Active Substances from the Extracts Based on Mixtures of Medicinal Plants by the Method of Maceration with the Use of Microwave Treatment and Exposure to Ultrasound

Zareta Talbievna Tazova, Ludmila Victorovna Lunina, Hazret Ruslanovich Siyukhov, Anzaur Adamovich Skhalyakhov, Olga Vyacheslavovna Marinenko

***Abstract*: This article presents the results of the studies aimed at intensifying the process of extracting biologically active substances (BAS) from medicinal vegetative raw material using the method of maceration with the use of microwave treatment and exposure to ultrasound. The comparative analysis of the obtained data about the yield of BAS has shown that the method of maceration in combination with ultrasound treatment (UT) is the most efficient for extracting the BAS from extracts under the following conditions of extraction: extractant — water, intensity of UT — 100 W/cm2; duration of UT — 10 seconds; treatment frequency — every 10 minutes; and total duration of extraction — 60 minutes.**

The use of these parameters allows intensifying the process of extraction by increasing the biological value of the extract due to the additional BAS extraction.

Keywords: medicinal herbs, phytocomposite mixtures, extracts, maceration, ultrahigh-frequency electromagnetic fields (UHF EMF) treatment, ultrasound treatment (UT), BAS, intensification.

I. INTRODUCTION

Medicinal herbs of the North Caucasus region are a rich source of functional ingredients that are currently used for enriching food products, including soft drinks.

It is known [1]–[3] that various methods of extraction are used for extracting BAS from medicinal herbs: maceration, percolation, repercolation, CO2 extraction, etc., with the use of water, organic solvents, ethyl alcohol, aqueous and alcohol solution, etc. as the extractant.

Despite the diversity of extraction methods and the development of modern technologies aimed at optimizing the process of extracting BAS from herbs, many issues remain open. For instance, many herbs are used in the form of aqueous extracts, while there are not enough studies devoted to the problem of increasing BAS release into the aqueous solution. However, water infusions and decoctions are the most physiological forms for the human organism.

To address the issue of intensifying the extraction process and increasing the yield of BAS from herb material, various methods of modifying the existing extraction methods are currently offered: processing herb material with enzymes and electrical current, laser and microwave irradiation of herb material before extraction, and the ultrasound and cavitation effect on the herb material during extraction.

Numerous studies performed in recent years [4], [5] have shown the advisability of the widespread use of ultrasound extraction as one of the most common methods of extracting BAS from herb material.

Ultrasound vibrations lead to intensive destruction of the cells in the herb material, which in turn accelerates extraction and increases the content of BAS in the extract.

Other modern methods of optimizing the extraction of BAS from herb material include high-frequency and microwave effects [6], which allow increasing the biological value of the ready product, increasing its output, and reducing the production areas. An important advantage of exposure to high frequency is the absence of the need to create significant temperature, humidity, and pressure gradients. However, some drawbacks of using the electromagnetic field should be pointed out. The effective penetration depth of electromagnetic waves into the material is 45 – 50 mm [6], therefore, with the increase in the thickness of the dried sample, the efficiency of treatment decreases, which is manifested in an increased duration of drying.

Purpose of the research is studying the effect of traditional maceration, maceration in combination with UT, and microwave treatment on the extraction of BAS from the extracts based on compositions of medicinal herbs for determining the most optimal extraction conditions.

Revised Manuscript Received on October 30, 2019.
* Correspondence Author
Zareta Talbievna Tazova, Maykop State Technological University, Maykop, Russia.
Ludmila Victorovna Lunina, Maykop State Technological University, Maykop, Russia.
Hazret Ruslanovich Siyukhov, Maykop State Technological University, Maykop, Russia.
Anzaur Adamovich Skhalyakhov, Maykop State Technological University, Maykop, Russia.
Olga Vyacheslavovna Marinenko, Maykop State Technological University, Maykop, Russia.

II. MATERIALS

The objects of the study were extracts from phytocompositional mixtures of various functional orientation. The adaptogenic extract is further referred to as Sample No. 1; the extract with antioxidant properties — as Sample No. 2; and the extract for preventing iodine deficiency disorders — as Sample No. 3.

Dry mixtures of medicinal herbs crushed at the temperature of 18 – 200C to the particle size of 1 – 2 mm were used for obtaining extracts:

Adaptogenic mixture No. 1. Components ratio, wt. %: common origanum (lat. Oríganum vulgáre) — 10, leaves of black currant (lat. Ríbes nígrum) — 10, minor duckweed (lat. Lémna mínor, leaves) — 10, leaves of common bilberry (lat. Vaccinium myrtillus L.) — 60, and common thyme (thyme) (lat. Thimus serpyllum L) — 10.

Mixture No. 2. A composition of herb materials for preventing iodine deficiency disorders. Components ratio, wt. %: leaves of walnut (lat. Juglans regia L.) — 60; purple coneflower (lat. Echinacea angustifolia) — 15; common thyme (thyme) (lat. Thimus serpyllum L) — 20; and leaves of black currant (lat.Ríbes nígrum) — 5.

Mixture No. 3. A composition of herb materials with antioxidant properties. Components ratio, wt. %: leaves of common bilberry (lat. Vaccinium myrtillus L.) — 60, leaves of walnut (lat. Juglans regia L.) — 15, leaves of black currant (lat.Ríbes nígrum) — 10, common origanum (lat. Oríganum vulgáre) — 5, and common thyme (thyme) (lat. Thimus serpyllum L) — 10.

III. METHODS

A. General description

To determine the mass concentration of phenolcarboxylic acids, rutin, and quercetin, capillary electrophoresis (Kapel-105 "M", Russia) was used according to the standard methods [7]-[9]. The method was based on obtaining an electrophoretogram via indirect detection of non-absorbing components of the sample. The Kapel-105 "M" capillary electrophoresis system features an ultraviolet photometric detector operating at the wavelength of 190 – 380 nm.

B. Algorithm

The experimental studies with extracting BAS from the experimental samples were performed by conventional maceration, maceration with additional UT, and microwave treatment with the following extraction conditions observed:
maceration method: extractant: water, the herb to extractant ratio: 1:10 (by weight), and the temperature of the extractant (water) t: +36 ± 20C.
This optimal temperature range was obtained by modeling laboratory experiments; the time of extraction was 30, 60, and 90 minutes, for each test sample, respectively.
UT effect:
Extractant: water,
the temperature of the extractant (water), t: +36 ± 20C,
the herb material to water ratio: 1:10,
UT intensity: 100 W/cm2,
UT duration: 10 seconds,
treatment rate: every 10 minutes, and
the total extraction time: 60 minutes.

For ultrasound exposure, the authors used the UZTA-0,4/22-OM ultrasound technological device of the Volna series with the following specifications:
the frequency of mechanical oscillations: (22 ± 1.65) kHz,
power: 400 VA,
power adjustment range, %: 30 – 100,
ultrasound intensity: not less than 50 W/cm2.
To obtain an extract with the use of microwave processing, crushed dry phytocompositional mixtures (mixture No. 1 – 3) with the weight of 4.0 – 5.0 g were placed in each container of the Minotaur microwave mineralizer, and 50 cm3 of water were added. The process of decomposition without pressure was started. Experimental samples were exposed to microwave effect for 1.5 and four minutes, respectively [10].
The MINOTAUR-1 device has the following specifications:
Microwave field energy: 600 Watt,
Frequency: 2,400 MHz.
Reactants used: water, acids, solvent mixtures.
The obtained extracts were diluted 10 times with distilled water and centrifuged at 6,000 rpm in Eppendorf tubes for three to four minutes. A ready sample was placed in the Kapel-105 "M" capillary electrophoresis device for analysis by the pre-defined calibration dependency.
To prepare the working electrolyte, 75 mg of boric acid weighed with the accuracy of up to 0.1 mg were placed into a 25 cm3 volumetric flask, 20 cm3 distilled water were added, the mixture was dissolved in a water bath at 700C, cooled, and 0.3 cm3 of 0.1n sodium hydroxide were added, after which the mixture was stirred and topped with distilled water to the mark. The detection wavelength was 254 nm.
Using the electrophoretogram, the mass concentration of the component in the studied sample was calculated (X) according to the established calibration characteristics by the formula (1):
$X = k \bullet C$ mg/dm3 (mg/kg) (1),
where k was the sample dilution factor defined as follows: $k = M/m$ (M was the amount (weight) of the sample,
m was the amount (weight) of the sample taken for the test),
C was the concentration of the component calculated by the calibration chart, mg/dm3.
The structural scheme of the study is shown in Fig. 1.

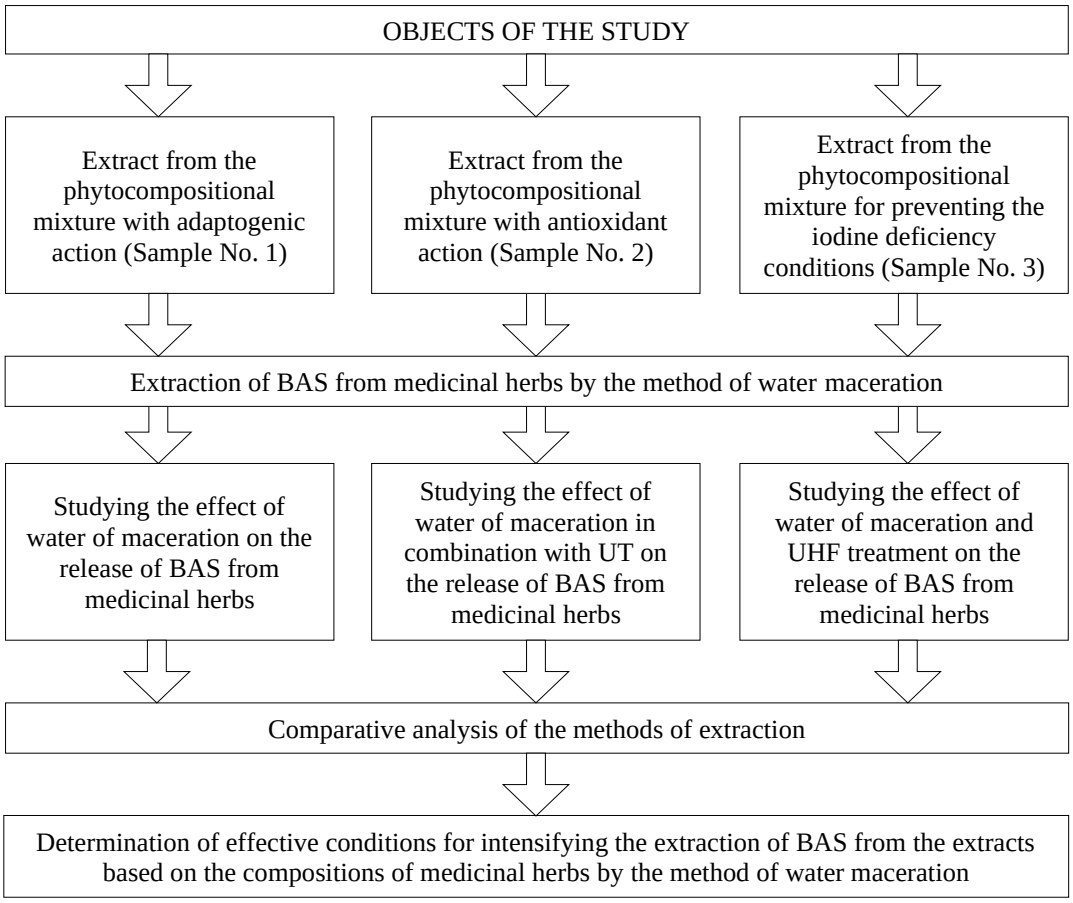

Fig. 1: The structural scheme of the study

IV. RESULTS AND DISCUSSION

In extracting BAS from the extracts of herb material using the traditional method of maceration (infusion) with water used as the extractant, the following results were obtained (Fig. 2 – 3).

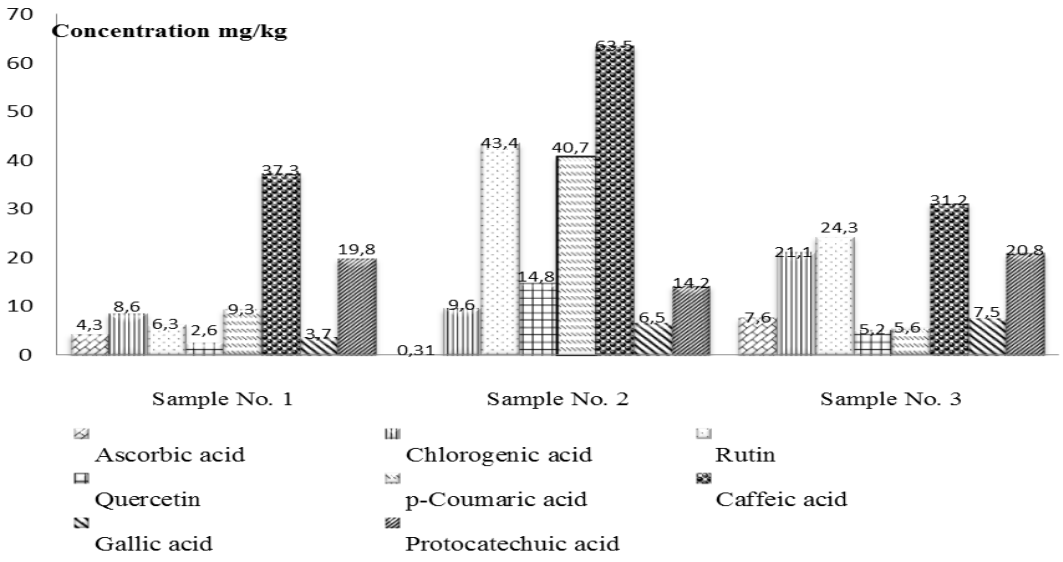

Fig. 2: Release of BAS from the experimental samples of extracts by the method of maceration in the following conditions: temperature t — +36 ± 2 0C, duration of extraction — 30 minutes

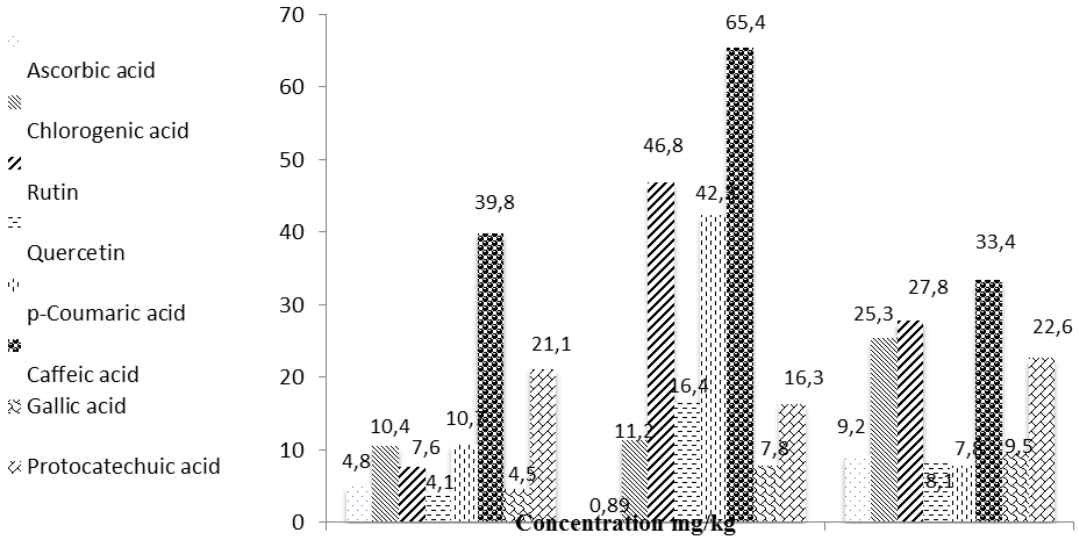

Fig. 3: The release of BAS from the experimental samples of extracts by the method of maceration in the following conditions: temperature t — +36 ± 2 0C, duration of extraction — 60 minutes.

By the results of the studies (Fig. 2 – 3) five phenolcarboxylic acids were identified in the test samples of the extracts (chlorogenic (C16N18O9), cumaric (HOOC-CH=CH-COOH), caffeic ((HO)2C6H3CH=CHCOOH), gallic (C7H6O5), and protocatechuic(C7H6O4.) acids), two flavonols (rutin and quercetin), and ascorbic acid.

It should be noted that their quantitative content in the test samples of the extracts was determined by the peculiarities of the chemical composition of the initial medicinal herbs.

The research of the authors showed that with the increase in the duration of extraction from 30 to 60 minutes, the release of some BAS increased to a certain extent.

For example, the content of rutin and quercetin (Fig. 2 – 3) in the experimental samples of the extracts decreased in the following order: sample No. 2 > sample No. 1 > sample No. 3. Also, an increase of the total content of phenolcarboxylic acids was observed: in sample No. 1 — by 10 %, in sample No. 2 — by 6 %, and in sample No. 3 — by 14 %. The maximum concentration of vitamin C was noted in the experimental sample of extract No. 2 obtained by extracting for 60 minutes (Fig.3).

The data about the release of BAS from the experimental samples of extracts by the method of maceration with the total extraction time of 90 minutes are shown in Fig. 4.

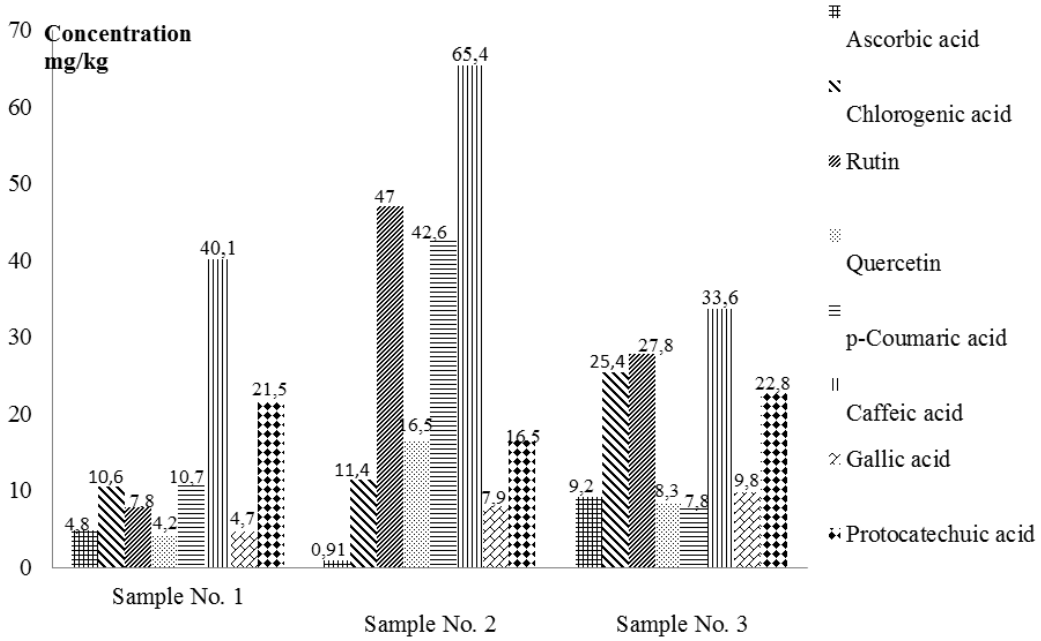

Fig. 4: The release of BAS from the experimental samples of extracts by the method of maceration in the following conditions: temperature t — +36±20C, duration of extraction — 90 minutes

The experimental data showed that increasing the duration of extraction to 90 minutes had virtually no effect on the activation of the BAS release from medicinal herbs, which speaks of the inappropriateness of increasing the duration. For instance, the release of rutin in sample No. 1 increased by only 4.4 %, in sample No. 2 — by 0.4 %, and in sample No. 3 its content remained virtually unchanged. The release of other BAS remained approximately at the level of the BAS release in case of extracting for 60 min.

Next, in order to intensify the process of BAS extraction from the extracts, experimental studies of the effect of UHF EMF and UT on the experimental samples of extracts were performed, following the extraction conditions.

The results are shown in Tables 1 – 3.

Table 1: BAS release in the experimental samples of the extracts (extraction conditions: UT intensity — 100 W/cm2; UT duration — five seconds; treatment frequency — every 10 minutes; the total duration of extraction — 60 minutes), mg/kg.

BAS name	Measurement unit	Experimental sample No. 1	Experimental sample No. 2	Experimental sample No. 3
Ascorbic acid	mg/kg	7.80	16.21	1.50
Chlorogenic acid	mg/kg	16.6	22.19	39.41
Rutin	mg/kg	18.8	114.52	86.12
Quercetin	mg/kg	4.31	6.23	7.55
p-Coumaric acid	mg/kg	32.62	165.21	78.96
Caffeic acid	mg/kg	44.21	142.32	198.53
Gallic acid	mg/kg	10.26	24.25	116.31
Protocatechuic acid	mg/kg	20.14	79.69	118.69

Table 2: BAS release in the experimental samples of the extracts (extraction conditions: UT intensity — 100 W/cm2; UT duration — 10 seconds; treatment frequency — every 10 minutes; the total duration of extraction — 60 minutes), mg/kg

BAS name	Measurement unit	Experimental sample No. 1	Experimental sample No. 2	Experimental sample No. 3
Ascorbic acid	mg/kg	8.7	25.2	5.5
Chlorogenic acid	mg/kg	25.3	28.0	65.7
Rutin	mg/kg	32.4	134.0	110.3
Quercetin	mg/kg	5.35	7.8	10.8
p-Coumaric acid	mg/kg	56.8	278.0	110.4
Caffeic acid	mg/kg	52.3	175.0	298.2
Gallic acid	mg/kg	15.6	35.4	148.6
Protocatechuic acid	mg/kg	27.8	91.2	131.5

Table 3: BAS release in the experimental samples of the extracts (extraction conditions: UT intensity — 100 W/cm2; UT duration — 15 seconds; treatment frequency — every 10 minutes; the total duration of extraction — 60 minutes), mg/kg

BAS name	Measurement unit	Experimental sample No. 1	Experimental sample No. 2	Experimental sample No. 3
Ascorbic acid	mg/kg	9.35	26.01	5.68
Chlorogenic acid	mg/kg	25.69	29.31	66.98
Rutin	mg/kg	33.04	135.02	115.21
Quercetin	mg/kg	5.98	9.12	10.98
p-Coumaric acid	mg/kg	63.21	282.29	112.39
Caffeic acid	mg/kg	54.82	178.25	299.39
Gallic acid	mg/kg	17.01	36.08	151.24
Protocatechuic acid	mg/kg	30.25	91.99	133.66

The obtained data (Table 1 – 3) show that BAS release into the extract increased with the increase in the duration of UT; with that, the content of BAS under UT with the duration of five seconds was the lowest, which explained the absence of the results of this experiment in the comparative analysis of UT with other durations.

It was found (Tables 2 – 3) that the content of rutin and quercetin in sample No. 1 with UT for 15 seconds was higher by 3 % than in case of UT for 10 seconds, in sample No. 2, by 2 %, respectively, and in sample No. 3, their content exceeded 4 %. The concentration of ascorbic acid varied as follows: sample No. 2 > sample No. 1 > sample No. 3 (Tables 2 – 3).

As to the content of phenolcarboxylic acids, their maximum concentration was observed in experimental samples 1 – 3 in case of UT for 15 seconds; it amounted to 1,572.56 mg/kg (Table 4), which was 1.02 times higher than their content in the test samples obtained by UT for 10 seconds (1,539.8 mg/kg).

Table 4: The release of phenolcarboxylic acids in the experimental samples of the extracts under the effect of UT (extraction conditions: UT intensity — 100 W/cm2; UT duration — 10 and 15 seconds; treatment frequency — every 10 minutes; the total duration of extraction — 60 minutes), mg/kg

BAS	Measurement unit	Sample No. 1	Sample No. 2	Sample No. 3
Phenolcarboxylic acids (UT – 10 sec.)	mg/kg	177.8	607.6	754.4
Phenolcarboxylic acids (UT – 15 sec.)	mg/kg	190.98	617.92	763.66

Next, due to the fact that the studied samples of extracts were supposed to be further used as the basis for producing functional soft drinks, it was necessary to assess their taste with the aim of identifying the most efficient extraction conditions, which would, in combination with the maximum BAS release, ensure high organoleptic characteristics of the extracts.

The results of assessing the taste are shown in Tables 5 – 6.

Table 5: Assessment of the taste of the experimental samples of the extracts (extraction conditions: UT intensity — 100 W/cm2; UT duration — 10 seconds; treatment frequency — every 10 minutes; the total duration of extraction — 60 minutes)

Indicators	Characteristic		
	Experimental sample No. 1	Experimental sample No. 2	Experimental sample No. 3
Appearance	Nontransparent liquid without impurities uncharacteristic of the extract.	Nontransparent liquid without impurities uncharacteristic of the extract.	Nontransparent liquid without impurities uncharacteristic of the extract.
Taste, color, smell	Golden amber liquid without shine. The smell has slight hints of dried fruit. The taste is pleasant and harmonious.	Deep amber liquid with shine. Pronounced herbal aroma with slight caramel tones. Full, harmonious, and pleasant taste.	Deep dark amber liquid without shine. Pronounced herbal aroma with hints of dried fruit. Astringent slightly bitter flavor.

Table 6: Assessment of the taste of the experimental samples of the extracts (extraction conditions: UT intensity — 100 W/cm2; UT duration — 15 seconds; treatment frequency — every 15 minutes; the total duration of extraction — 60 minutes)

Indicators	Characteristic		
	Experimental sample No. 1	Experimental sample No. 2	Experimental sample No. 3
Appearance	Nontransparent liquid without impurities uncharacteristic of the extract, slight opalescence observed.	Nontransparent liquid without impurities uncharacteristic of the extract, slight opalescence observed.	Nontransparent liquid without impurities uncharacteristic of the extract, slight opalescence observed.
Taste, color, smell	Deep amber liquid without shine. The aroma has strongly pronounced hints of dried fruit. Pronounced bitter astringent taste.	Deep dark amber liquid with shine. Pronounced herbal aroma, pronounced bitter astringent taste.	Deep dark amber liquid with shine. Pronounced herbal aroma, pronounced bitter astringent taste.

As shown by the results of the studies (Tables 5, 6), the experimental samples of the extracts obtained with exposure to UT for 10 seconds at 10 minute intervals, and the duration of extraction of 60 minutes had more pleasant taste and aroma which were characteristic of the initial material than the extracts from the samples obtained in a similar way with exposure to UT for 15 seconds, as evidenced by the pronounced herbal aroma, the bitter, astringent taste, and the light opalescence of the extract. The authors believe that this was due to the additional release of unidentified BAS that influenced the taste and aroma characteristics.

The results of the taste analysis were the basis for preliminary selection of the efficient conditions of extracting BAS from phytocompositional mixtures of medicinal herbs using UT. The best organoleptic characteristics were noted in the following conditions of UT of the extracts: UT intensity — 100 W/cm2; UT duration — every 10 seconds; treatment frequency — 10 minutes; and the total extraction duration — 60 minutes.

In the next stage, the crushed dry phytocompositional mixtures were exposed to microwave treatment for 1.5 and four minutes, respectively, according to the conditions of extraction [10].

The results of the experiment are shown in Tables 7 – 9.

Table 7: Release of BAS from the test sample of extract No. 1 (extraction conditions — microwave exposure for 1.5 and four minutes, respectively, the energy of the SHF field — 600 W, frequency — 2,400 MHz), mg/kg.

BAS name	Measurement unit	Experimental sample No. 1 Duration of microwave exposure — 1.5 min	Experimental sample No. 1 Duration of microwave exposure — four minutes
Ascorbic acid	mg/kg	5.9	6.5
Chlorogenic acid	mg/kg	17.3	22.0
Rutin	mg/kg	26.0	28.0
Quercetin	mg/kg	7.4	4.4
p-Coumaric acid	mg/kg	23.2	52.3
Caffeic acid	mg/kg	32	47.1
Gallic acid	mg/kg	1.6	12.3
Protocatechuic acid	mg/kg	18.3	23.6

The data in Table 7 show that in the experimental sample No. 1 with the microwave exposure for four minutes, the maximum release of phenolcarboxylic acids and vitamin C was noted, which, compared to the microwave exposure of 1.5 min, was 1.7 times higher for phenolcarboxylic acids, and 1.1 times higher for ascorbic acid. At the same time, the total content of rutin and quercetin had negative dynamics, their content reduced 1.03 times with the increase in the duration of microwave exposure (Table 8).

Table 8: Release of BAS from the test sample of extract No. 2 (extraction conditions — microwave exposure for 1.5 and four minutes, respectively, the energy of the SHF field — 600 W, frequency — 2,400 MHz), mg/kg

BAS name	Measurement unit	Experimental sample No. 2 Duration of microwave exposure — 1.5 min	Experimental sample No. 2 Duration of microwave exposure — four minutes
Ascorbic acid	mg/kg	0.6	23.8
Chlorogenic acid	mg/kg	24.1	25.0
Rutin	mg/kg	65.0	120.0
Quercetin	mg/kg	11.8	4.7
p-Coumaric acid	mg/kg	83.3	250.0
Caffeic acid	mg/kg	30.3	167.0
Gallic acid	mg/kg	8.7	33.6

According to the result of the research (Table 8), the total content of phenolcarboxylic acids in experimental sample No. 2 was 164.3 mg/kg after microwave exposure for 1.5 min, and 563.2 mg/kg — after four minutes. Therefore, the duration of exposure contributed to increasing the release of phenolcarboxylic acids almost 3.4 times. The content of quercetin and rutin increased by 62.4 %. The highest concentration of ascorbic acid was noted after microwave exposure for four minutes, which almost 40 times exceeded the data obtained after microwave exposure for 1.5 min.

Table 9: Release of BAS from the test sample of extract No. 3 (extraction conditions — microwave exposure for 1.5 and four minutes, respectively, the energy of the SHF field — 600 W, frequency — 2,400 MHz), mg/kg

BAS name	Measurement unit	Experimental sample No. 3 Duration of microwave exposure — 1.5 min	Experimental sample No. 3 Duration of microwave exposure — four minutes
Ascorbic acid	mg/kg	4.7	0
Chlorogenic acid	mg/kg	3.2	63
Rutin	mg/kg	14.0	108.5
Quercetin	mg/kg	1.0	6.0
p-Coumaric acid	mg/kg	3.7	107.8
Caffeic acid	mg/kg	33.0	290.0
Gallic acid	mg/kg	9.8	143.6
Protocatechuic acid	mg/kg	21.5	127.0

In experimental sample No. 3, the highest total content of phenolcarboxylic acids (Table 9) was noted after microwave exposure for four minutes (157.3 mg/kg), which was almost two times higher than after microwave exposure for 1.5 minutes (92.1 mg/kg). By the content of quercetin and rutin, the leader was the sample exposed to microwave treatment for four minutes (7.6 times).

Next, the content of BAS in the test samples of the extracts obtained by maceration in combination with UT and microwave treatment was analyzed.

The results of the studies are shown in Fig. 5 – 7.

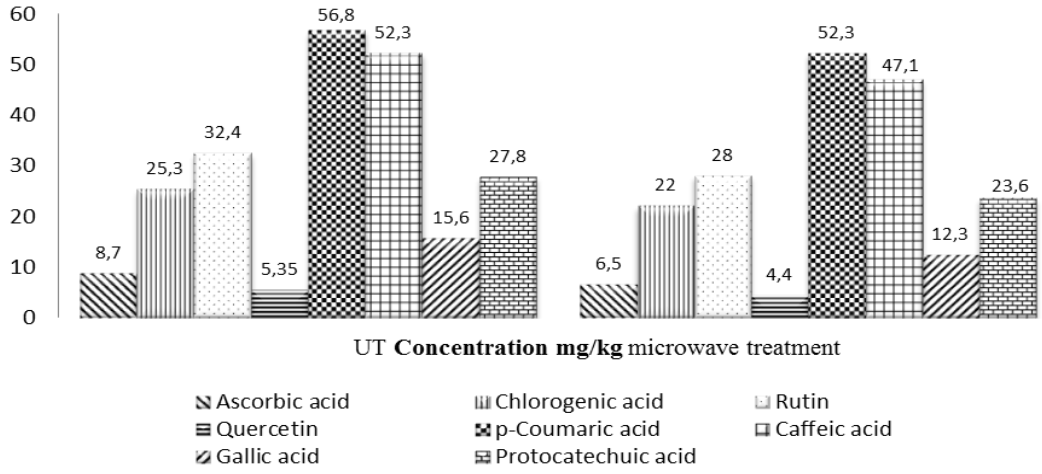

Fig. 5: BAS release from sample No. 1 obtained by various methods of extraction in the following conditions: microwave exposure for four minutes, SHF field energy — 600 Watt, frequency — 2,400 MHz; UT effect — 100 W/cm2; UT duration — 10 seconds; treatment frequency — every 10 minutes; and the total duration of extraction — 60 minutes), mg/kg

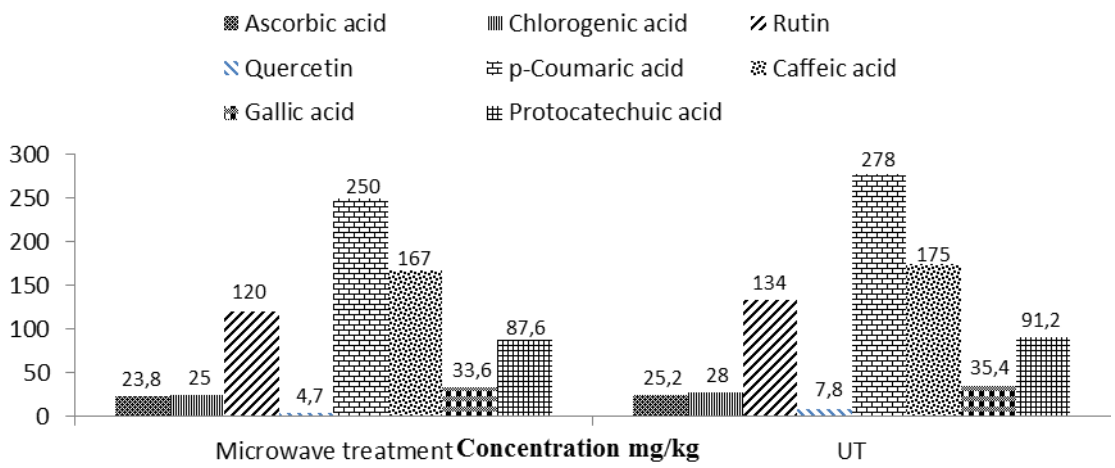

Fig. 6: BAS release from sample No. 2 obtained by various methods of extraction in the following conditions: microwave exposure for four minutes, SHF field energy — 600 Watt, frequency — 2,400 MHz; UT effect — 100 W/cm2; UT duration — 10 seconds; treatment frequency — every 10 minutes; and the total duration of extraction — 60 minutes), mg/kg

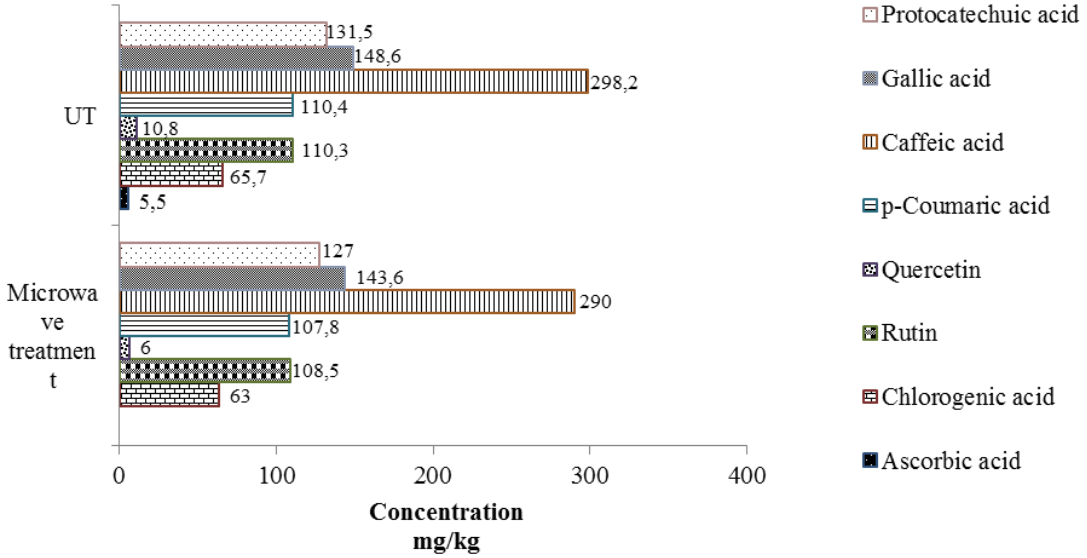

Fig. 7: BAS release from sample No. 3 obtained by various methods of extraction in the following conditions: microwave exposure for four minutes, SHF field energy — 600 Watt, frequency — 2,400 MHz; UT effect — 100 W/cm2; UT duration — 10 seconds; treatment frequency — every 10 minutes; and the total duration of extraction — 60 minutes), mg/kg

Comparative analysis of the results of BAS release with the use of various methods of extraction showed that the UT method, compared to microwave exposure, had the best results.

For example, in sample No. 1, the content of phenolcarboxylic acids was 177.8 mg/kg, which was 1.13 times higher than the results of microwave extraction. With that, it should be noted that the content of chlorogenic acid that had high antioxidant activity was higher by 15 %, of p-Coumaric acid — by 9 %, of caffeic acid — by 11 %, of gallic acid — by 27 %, and of protocatechuic acid — by 18 %. The content of ascorbic acid was 1.3 times higher than in the sample obtained by microwave exposure. The content of rutin was higher by 16 %, and of quercetin — by 22% in the extract obtained using UT (Fig. 5).

In sample No. 2, the release of phenolcarboxylic acids was 607.6 mg/kg. With that, the release of chlorogenic acid was higher by 12 %, of p-Coumaric acid — by 11 %, of caffeic acid — by 5 %, of gallic acid — by 5 %, and of protocatechuic acid — by 4 %, compared to the method of microwave exposure. Significantly higher amounts of labile vitamin C — by 6 %, of rutin and quercetin — by 12 % and 66 %, respectively, were noted.

Sample No. 3 obtained by using the method of maceration with additional UT contained 754.4 mg/kg of phenolcarboxylic acids; a high enough concentration of caffeic acid — 298.2 mg/kg, which was 3 % higher than in the microwave method (290.0 mg/kg), of gallic acid – 148.6 mg/kg, of protocatechuic acid — 131.5 mg/kg, respectively, was also noted, which was by 3 % and 4 % higher than in the test sample of the extract obtained by the microwave

method. The amount of chlorogenic and p-Coumaric acids also increased 1.04 times and 1.02 times, respectively (Fig. 7).

Based on the experimental data (Fig. 7), the content of rutin and quercetin in various conditions of extraction using UT and microwave exposure amounted to 110.3 mg/kg and 108.5 mg/kg for rutin, and 10.8 mg/kg and 6 mg/kg for quercetin, respectively.

V. CONCLUSION

1) It has been found that for the extraction of BAS from compositions of medicinal herbs, it is advisable to use the traditional method of maceration with prepared water as the extractant. The choice of water was determined by its selectivity, accessibility, chemical indifference, as well as the maximum dissolution rate, and explosion and fire safety. It should also be noted that water infusions and decoctions are the most physiological forms for the human organism.

2) It has been found that during the extraction using the method of maceration, the highest release of BAS is observed in the following conditions: temperature t — +36±20C, duration of extraction — 60 minutes, since the research studies show that increasing the duration of extraction to 90 minutes does not have a significant effect on the release of BAS.

3) The comparative analysis of the efficiency of releasing BAS from herb material into the extract has shown that the use of water maceration in combination with UT of the extract is more efficient than microwave treatment. The following technological parameters of UT of the extracts obtained based on compositions of medicinal herbs have been experimentally determined:

– UT intensity — 100 W/cm2; UT duration — 10 seconds; treatment frequency — every 10 minutes; and the total extraction duration — 60 minutes.

The use of these parameters allows intensifying the process of extraction by increasing the biological value of the extract due to the additional BAS extraction.

ACKNOWLEDGMENT

The studies were performed in the framework of the Federal Target Program "Research and Development in the Priority Areas of Developing the Scientific and Technological Complex of Russia for the years 2014 — 2020" on topic "Development of the Technologies for Producing High-Quality and Safe Functional Drinks with the Use of Biologically Active Components from Nonconventional Herb Material of the North Caucasian Region", Agreement No. 14.574.21.0174. The unique identifier of the work (project) is RFMEF157417X0174).

NOVELTY

It has been experimentally found that for intensifying the processes of BAS extraction from the extracts of medicinal herbs, the most effective method is maceration in combination with UT. The UT parameters that ensure an increased release, and improve the quality of BAS upon extraction from herb material have been determined.

REFERENCES

1. A. S. Konichev et al. “Traditsionnye i sovremennye metody ekstraktsii biologicheski aktivnykh veshchestv iz rastitelnogo syrya: perspektivy, dostoinstva, nedostatki” [Traditional and modern methods of extracting biologically active compounds from herb material: prospects, advantages, disadvantages], *Bulletin of Moscow State Open University*, Series Natural Sciences, 3, 2011, pp. 49 – 54.
2. G. K. Goncharenko, E. I. Orlova. “Kinetika ekstragirovaniya rastitelnogo materiala” [Kinetics of plant material extraction], *Medical Industry of the USSR*, 3, 1992. pp. 89 – 100.
3. I. N. Tokarev, A. Y. Karev, R. G. Sazkhiev “*Sposob prigotovleniya vodnykh ekstraktov rastenii”* [A method for preparing aqueous plant extracts], Pat. No. 2146938 Russian Federation, 98122603/14 app. 15.12.1998; Published on 27.03.2000.
4. C. M. Galanakis “Recovery of high added-value components from food wastes: conventional, emerging technologies and commercialized applications”, *Trends in Food Science & Technology*, 26(2), 2012, pp. 68 – 87.
5. S.R. Shirsath, S.H. Sonawane, P.R. Gogate “Intensification of extraction of natural products using ultrasonic irradiations—A review of current status”, *Chem Eng Process Intensif*, 53, 2012, pp. 10 – 23.
6. O. Morozov et al. Promyshlennoe primenenie SVCH – nagreva [Industrial application of microwave heating], *Electronics: Science, Technology, Business*, 3. 2010, p. 266
7. GOST R 53193-2008. Alcoholic and non-alcoholic drinks and beverages. Determination of caffeine, ascorbic acid and its salts, preservatives, and sweeteners using capillary electrophoresis method;
8. StP00668034-23-15-2009. Materials of vegetable origin. Method of determination of the mass concentration of ascorbic, chlorogenic and caffeic acids using capillary electrophoresis method.
9. STO 00668034-097-20018. Biological objects, products of processing. Determination of the mass concentration of quercetin and rutin by the method of high-performance capillary electrophoresis.
10. Y. F. Yakuba, A. P. Kuznetsova, M. S. Lozhnikova. *Primenenie kapillyarnogo elektroforeza i ekstraktsii v pole SVCH dlya analiza rastitelnogo syrya* [The use of capillary electrophoresis and extraction in the microwave field for the analysis of herb material]//Proceedings of III All-Russia Symposium Separation and Concentration in analytical chemistry and radiochemistry. Krasnodar, 2011, p. 153.