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APPLICATIONS OF MICROWAVE FIELDS IN FOOD TECHNOLOGY: PROCESSING, PRESERVATION AND EXTRACTION*

Microwave radiation, as a method of heat supplying, is not so far widely used in food industry. However, this method is promising because of the moisture present in food products, which is heated extremely intense. A number of scientific studies confirm that microwave radiation significantly intensifies processes of dehydration and extraction. This study presents the results of using MWAE – the microwave assisted extraction, – in the production of coffee, rosehips, medicinal herbs and other extracts. The dependencies of the extraction kinetics, thermograms and results of the study of obtained extracts qualitative parameters are presented. Different types of extraction units were used for different products: open vessel type, closed vessel type, operating at atmospheric and at reduced pressure. The extracting from ground coffee shows high values of mass transfer coefficients: [5.8, ... 8,8·10-8] m/s, which indicates a high degree of the process intensification in comparison with methods of battery extraction. The process temperature did not exceed 100 °C, so there are no cellulose hydrolysis processes, which reduce the quality of the coffee extract. An extractor of a closed type was used for extracting from rose hips. The extraction was carried out under reduced pressure. Analysis of the obtained extract showed a high content of vitamin C and beta-carotene, compared with the extracts obtained in the thermostat.

1. ANALYSIS OF THE EXPERIENCE OF THE MICROWAVE FIELD USAGE IN FOOD TECHNOLOGIES

As known, microwave (MW) radiation is the frequency range between 300 GHz ... 300 MHz, which takes place between infrared radiation and radio frequencies in the electromagnetic spectrum. Most microwave heating systems use frequency of

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* Invited paper.

2450 MHz, which is used by home microwave ovens. In Ukraine, the following frequency ranges are permitted for industrial use: 1 915 ± 13 MHz; 2 2450 ± 50 MHz; 3 5800 ± 75 MHz; 4 24125 ± 125 MHz.

Of the four microwave ranges, the first two, mostly, are used in the food industry. The second frequency range is used in home microwave ovens and both are used for industrial heating [1].

The main difference between microwave heating and convective heating methods is the absence of intermediate heat carriers. Energy in this case is transferred not according to classical scheme "generator - environment - product", but directly from generator to product "generator - product", and only then heat is distributed convectively and conductively to the product and environment.

When MW energy enters the sample, it is absorbed depending on the scattering factor. It is believed that penetration depth is almost infinite for materials that conduct microwave energy and zero for materials with high reflectivity, such as metals. The scattering factor is of great importance for processed samples. Since, energy is rapidly absorbed and dissipated when MW pass through the sample, the greater the scattering factor, the less the MW energy of a given frequency will penetrate into sample [2].

Recent studies confirm high intensification of mass transfer processes in the MW field. However, despite the large number of MW extraction studies, industrial MW extractors are not commercially available today. MW extraction devices have been used in research and experiments in the field of pharmaceuticals and organic chemistry. Their characteristics are shown in table 1 [3-5]. Descriptions of high-performance product that could be used in food production were not found or produced.

The MW extractor designs are being refined. In parallel MW extractors are developed in different countries, experiments are conducted for different types of raw materials, depending on production needs. For the extraction of cocoa leaves in the research of the Department of Chemical Engineering, University of Malaysia (Malaysia), an apparatus based on a household MW oven (Samsung MW718), equipped with additional regulators for implementation of two-stage and discrete extraction modes were used [6]. In this case, only microwave field was used, but with the help of an advanced control system different operating modes were implemented: a step change of the power of microwave field, a mode with interruptions of the field influence, a saw-like change of the power of microwave field.

A combined technique for extracting polysaccharides from *Fortunella margarita* (kumquat) was used in research by the Tagalog Science Center, in collaboration with the College of Food Sciences, Fujian University of Agriculture and Forestry (China) [7]. In combination with MW and ultrasonic extraction techniques, it is possible to significantly accelerate the process and purity of isolated polysaccharides. The technique of ultrasonic microwave synergistic extraction (UMSE) uses cavitations vibration and high energy potential of MW energy.

The combined extraction technique was also used in the research of Sun Yatsen University (China). They call their method of extraction "a technique of hybrid field dispersive extraction in a solid-liquid-solid system". Target components were organochlorine pesticides contained in tobacco [8].

Also, combined extraction techniques are used in their research by the experts of Chin-Yi National University of Technology (Taichung, Taiwan). The technique of hybrid MW thermal extraction is used to obtain biologically active components from mulberry root [9].

Table 1. The overview of modern microwave devices and their main features [3-5].

Device	Notes
CEM Corporation; MARS (open (OTC) and closed type (CTC) of construction)	Adjustable power up to 1600 W; possibilities to adjust the reflux condensers, use of additional reagents, additional mixing, etc.; capacity up to 40 containers (75 ml) in closed system and one container in 5 ml in open mode. [50, … 300] ° C, depending on capacity and pressure rise up to 34 bar
CEM Corporation; Discover series (OTC and CTC)	Focusing microwaves up to 300 W with high efficiency; single camera mode with capacity up to 300 ml; interaction with autosampler from 12 to 96 points; [80, … 300] ° C at pressures up to 21 bar; dynamic mode of operation during continuous operation or in the flow stop mode
Milestone; Ethos EX Lab; (OTC and CTC)	From 1 to 100 g; adjustable power up to 1600 W; adjustable motors for normal operation, high throughput and large sample analysis; a magnetic stirrer to ensure uniform mixing, solvent evaporation and recovery after treatment; pressure control up to 35 bar
Milestone; Ethos Digestion Lab series (OTC and CTC)	Convenience for welding procedures; maximum working pressure is 100 bar; different configurations of agitator motors.
Anton Paar; Multiwave 3000; (CTC)	Adjustable power up to 1400 W; mixing device and rapid cooling system; processing up to 48 samples at a time; controlled evaporation of the solvent to dry the extract
Aurora; Biomed; Transform 800; (CTC)	Processing up to 10 samples; maximum modes are 250 ° C and 55 bar; centralized control of pressure and temperature
Sineo; MDS-8; (CTC)	Adjustable power up to 1200 W; processing up to 10 samples; maximum modes are 300 ° C and 80 bar
Sineo; MDS-10; (CTC)	Adjustable power up to 1800 W; processing up to 15 samples; maximum modes are 300 ° C to 15 bar

In general, it can be noted that MW field using gives a positive result for extraction from plants and vegetable raw materials.

Literature does not give a clear explanation of the causes of intensification precisely when applying a microwave field, a clear mathematical description of the process and transition to a meaningful mathematical model of extraction processes under the influence of microwave field on plant structures.

When extracted from plant raw materials, the main barrier to extractive substances in the extract is the cell membrane. In the works of scientists of Ukrainian scientific centres [10] it is emphasized that the destruction of cell walls can intensify the process of extraction. Different methods can be used for this: chemical, mechanical or electro physical, to which MW extraction applies.

In the research of the Department of Processes, Equipment and Energy Management MW technologies for process intensification have been used since late 90's. Positive results have been achieved in coffee and coffee raw materials extraction [10-11], cognac production, flax and amaranth oil extraction. In study of extraction processes, it is determined that the phenomenon of barodiffusion occurs under the action of MW field [10]. Barodiffusion phenomena and its in-depth study became the basis for development of the direction of extraction with involvement of MW radiation.

Next step in the development of microwave assisted extraction (MWAE) apparatus is to implement continuous operating modes and increase productivity. Work in this area has begun relatively recently mode of continuous movement of the solvent through the raw material layer was implemented in the works of O.G. Burdo, S.G. Terziyev and T.L. Makeevskaya when working with coffee sludge [11].

2. RESEARCH MATERIALS AND METHODS

2.1. EXPERIMENTAL BENCH AND EQUIPMENT

The most of studies were conducted on laboratory plants, developed by the authors of this article. The power supply in MW extractors was carried out by means of impulse control. There was specified the total time of electro physical exposure and the frequency of magnetron activation. The MW unit was connected to the mains via a combined K-50 type measuring kit.

Using the wattmeter of this device was determined by power consumption of the plant. Accuracy of MW timer operation was checked with stopwatch. Portable MW radiation leakage tester EM0328 indicates intensity of the electromagnetic field in range [0, ... 10] mw/sm. Power consumption of 230 VAC, 50 Hz, 1,450 W, in magnetron mode output power was 900 W, frequency 2,450 MHz. The error of the timer cycles is near the 0.3%.

2.2 ANALYTICAL INSTRUMENTS AND EXPERIMENTAL TECHNIQUES

During the processing of results of the experiments, there is a need to calculate the thermo physical and physicochemical properties of the extracts. Temperatures ($t_к$, $t_н$) were measured at inlet and outlet of the extractor solution using a chromel alumel

thermocouple and a Fluke 561 HVA CPro digital measuring instrument, and by the DAN -1000 contact thermometer.

Diffusion coefficients D for "coffee bean - water" system have been identified in the literature [10] and average values of diffusion coefficient for the "solid phase - water" system have been established at 25 °C. Influence of ambient temperature (*t*, ºC) on average values of the diffusion coefficient for processing experimental data was taken into account by the ratio 1 [11]:

$$D(t) = (1.97 \cdot 10^{-8} \cdot t^3 + 3.71 \cdot 10^{-5} \cdot t^2 + 3.76 \cdot 10^{-3} \cdot t + 0.09) \cdot 10^{-9} \quad (1)$$

Since in case of the phenomenon of barodiffusion partial destruction of the plant cells walls and the capillaries and turbulence of the boundary layer occur, traditional model of mass transfer is changing. A common barodiffusion flow JM occurs, in which it is impossible to distinguish the internal and external diffusion components. Thus, the intensity of mass transfer can be characterized by the effective mass coefficient βE, which is calculated by the classic formula (2).

$$\beta_E = \frac{V_E \cdot 100}{F_K \cdot \tau \cdot (C_n - C_p)}, m/s \quad (2)$$

where V_E – volume of the extract, m^3; F_K – phase contact area, m^2; C_n – current concentration in raw materials; C_p – equilibrium concentration in raw materials; τ – extraction time, s.

During the generalizing of the experimental studies, parameters of the criterion equation (3) and dependences for the calculation of the phase equilibrium conditions were determined.

$$St_m = A(Re)^m \cdot (Sc)^n (\Pi)^b \cdot (Bu)^p \cdot (D)^y \quad (3)$$

where St_m Stanton number of mass-transfer; *Re* Reinolds number; *Sc* Shmidt number; Π parametrical number; *Bu* Burdo number; *D* diffusion coefficient; *A, m, n, p, b, y* – experimentally defined constants

Error in estimating these parameters depends on accuracy of the calculations of similarity numbers: Stanton *(St_m)*, Schmidt (*Sc)*, Reynolds *(Re)*, Burdo *(Bu)*, which in turn are determined by errors of estimation of geometrical and mode characteristics of the extraction process obtained by means of measurements. To reduce systematic errors determined by error of the device, devices with an accuracy class of [0.5, ... 1] were used. Work with the devices was carried out in accordance with rules given in the passports and operating instructions.

2.3. THE INSTRUMENTAL ERRORS

Direct measurements give estimates of height and length of the channel, time, radiation power, changes in volume of the solvent in a measuring container, volume of the solution, its optical density and mass of coffee raw materials.

Limit of the allowable relative error of direct measurements, which are determined by accuracy class of the instrument and magnitude of the measured value, are given in table 2. Upper and lower magnitudes of the measured values were taken into account in calculation of the limit of permissible relative error. The RMS (root-mean-square) errors of the similarity numbers and dimensionless parameter Π consist an error of changes in the values (υ, ρ, D, r, c_p).

Table 2. Limits of allowable error of direct measurements

№	Measured value			Allowable error	
	Name		Marking	Absolute	Relative
1	Time, s		τ	1	1 / 300 = 0.003 1 / 1,800 = 0.0006
2	Height, mm		H	1	1 / 27 = 0.037 1 / 20 = 0.05 1 / 14 = 0.07 1 / 8 = 0.125
3	Length, мм		L	1	1/200 =0.005
4	Temperature, °C	Thermocouple DAN-1000	T	0.5	0.5/30 = 0.017 0.5/75 =0.007
4	Temperature, °C	Thermometer	T	0,1	0.1/10 = 0.01 0.1/100 = 0.001
		Pyrometer GM320		1.5	1.5/330=0.0045
		Thermal imaging pyrometer FLIR TG54		1	1/100=0.001
5	Optical density	Refractomether	E	0.001	0.001/1.3334 = 0.0007
		«SPEKOL»		1	1/15 = 0.07 1/100=0.01
6	Concentration	HI 96801, Hanna Instruments	C	0.2	0.2/100=0.002
		EC /TDS / COM-100		2	2/100=0.02
7	Weight, g		$G_з$	0.001	0.001/180 = 0.000006 0.001/335 = 0.000003
8	Volume, l		V_P	0.01	0.001/5 = 0.002 0.001/20 = 0.00005

It should be noted that even with increased values of input parameter errors (δRe = ± 2.3%, δSc = ± 1.13%, δBu = ± 5.8%), the final error δSt_m of the criterion equation does

not exceed 7%. That is, the standard error of the mathematical model contains an experimental error, not exceeding 7%.

3. RESEARCH RESULTS AND DISCUSSION

3.1. RESEARCH RESULTS

The results of studies of hydraulic processes in MW modules of the apparatus of continuous action should to determine the maximum concentration in solid phase, the kinetics of extraction under conditions of change of mode parameters are necessary to determine modes of operation, in particular to avoid removal of the product from the extractor or loss of solvent. Main factors affecting the extraction process are temperature (T, °C) and power (N, W) of MW radiation and hydraulic module (ζ), volume consumption of solvent (V_p, kg/s), equivalent particle size (d_e, mm), thickness of product layer (σ, mm) (table 3).

Experiments were conducted using coffee beans of different grinding tonnage and whole grains. Separation of coffee into fractions was performed using a set of laboratory sieves. The mass exchange module was filled with 10 mm product.

Table 3. Range of experimental studies of hydraulic processes

Parameters	ΔP, Pa	$V \cdot 10^6$, m^3/s	$\delta \cdot 10^3$, m	d, mm	τ, s
min	80	1.2	8	0.63	60
max	310	5.3	27	7	720

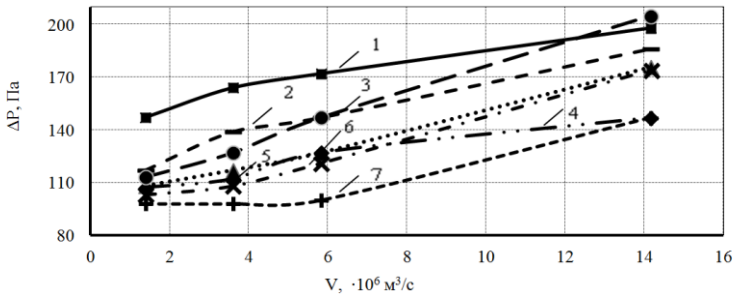

Fig. 1. Hydrodynamic situation in the module depending on change in the speed of solvent and the particle size: 1 – less than 0,8 mm; 2 – [1, … 2] mm; 3 – 1/2 of coffee bean; 4 – [2, … 2,5] mm; 5 –1/4 of coffee bean; 6 – [2,5, … 3] mm; 7 – whole coffee bean.

As consumption of the solvent changed, product level in the module varied accordingly. Different grinding modes of solvent are characteristic for coffee of different grinding tone (fig. 1).

Porosity of the raw material layer was experimentally determined depending on change in the equivalent particle diameter of product (table 4).

Table 4. Porosity change depending on the particle size of ground coffee beans

d, mm	> 0.8	[1,…2]	[2, …2.5]	[2.5, …3]
ε	0.441	0.458	0.475	0.491

Experimental data determined Reynolds and Euler numbers, equivalent dimensionless particle diameter *D*. Mathematical model of hydraulic processes in the extractor is specified:

$$Eu = 6.836 \cdot Re^{-1.06} D^{1.2} \quad (4)$$

Equation (4) can be used to estimate the hydrodynamic situation in mass transfer modules and to design MW extractors.

To adequately evaluate results of the experiment, calibration of the energy supply system under conditions of movement of the solvent through one module and a block of mass exchange modules was carried out.

Most of the experiments were aimed at studying the kinetics of extraction from coffee. Dispersion of the milled coffee particles varied in the range $[0.63 \cdot 10^{-3}, \ldots 3 \cdot 10^{-3}]$ m. Experimental studies of process of mass transfer in the system "raw material - solvent" under the conditions of MW energy supply were carried out in range of parameters, which are shown in table 5.

Table 5. Range of experimental studies

Weight of coffee in 1 module $G_к$, kg	Layer thickness $\delta \cdot 10^3$, m	Solvent consumption $V \cdot 10^6$, m^3/s	Temperature *t*, ºC	Specific microwave power *N*, W/kg
[0.02, … 0.35]	[4, … 27]	[1, … 4]	[20, … 90]	[270, … 900]

From the dependencies (fig. 2) dynamics of the depletion of water-soluble extractive solids from grains is noticeable.

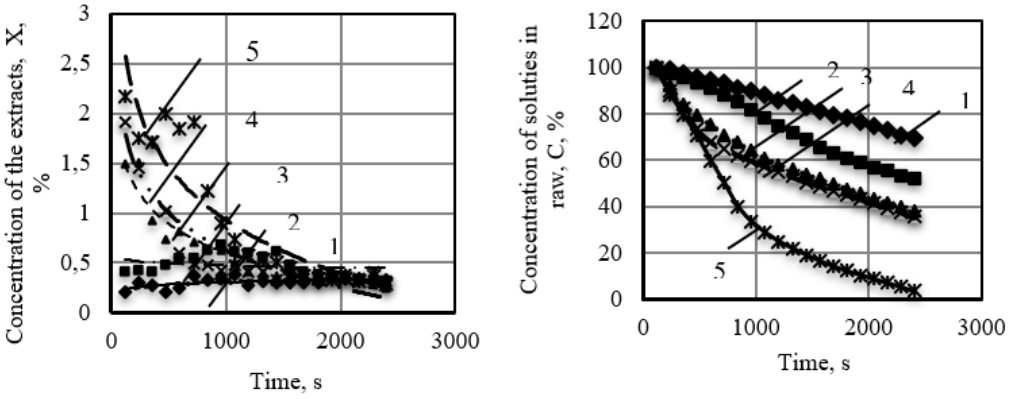

Fig. 2. Exhaustion of dry water-soluble substances (d.s.) in extract and in the raw material depending on intensity of the action of MW field: 1 – 90 W; 2 – 270 W; 3 – 450 W; 4 – 630 W; 5 – 900 W.

Studies have shown (fig. 2) that increasing the specific power of MW energy from 90 to 900 watts can increase the output of extractives from coffee beans more than twice and significantly reduce duration of the extraction process, and, consequently, reduce energy intensity of the coffee extract production process. In order to study completeness of the exhaustion of solids from coffee at different costs of the solvent, study at a specific power of 270 W was conducted (m=50 g, δ=[1, … 2] mm). Results of the experiment are shown in fig. 3. From the dependencies obtained, it is seen that with increasing of the solvent flow we obtain an extract with a lower concentration of solids

Final concentration of the extract is also significantly affected by the "solid-solvent" ratio (hydraulic module). To evaluate its impact, a study was conducted using ground coffee (δ=[1, … 2] mm) on laboratory bench, which consisted of an MW camera with a power unit and reflux condenser, which kept a constant volume of solvent (200 ml), a specific power of 270 W.

Used ground coffee samples in 2, 10 and 50 g for 1:100, 1:20 and 1:4 hydraulic modules respectively. Analysis of the results showed that the complete extraction of solids from coffee was 20 %, 15 % and 12 %, which indicates a better extraction of water-soluble substances when using a larger hydraulic module. However, with a large hydraulic module, concentration of solids in the extract is lower.

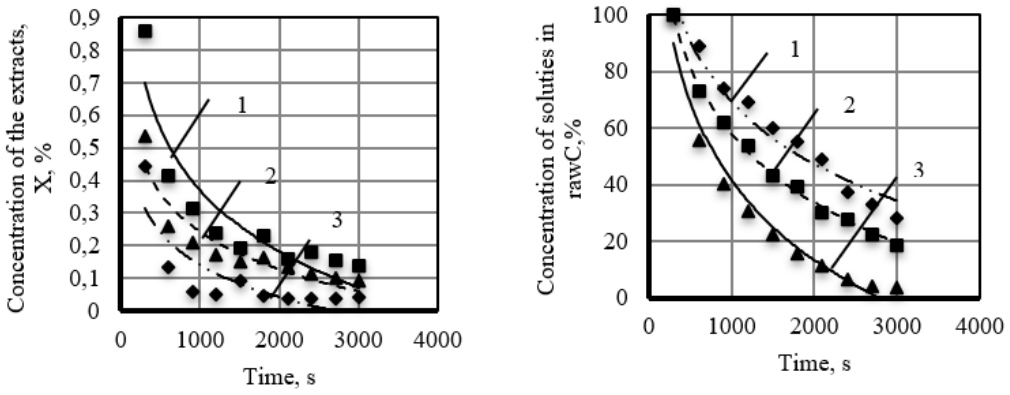

Fig. 3. Exhaustion of solids from ground coffee at different solvent consumption: 1 – $1.2 \cdot 10^{-6}$ m^3/s; 2 – $4.2 \cdot 10^{-6}$ m^3/s; 3 – $7.7 \cdot 10^{-6}$ m^3/s.

During the extraction under conditions of continuous movement of solvent it is difficult to estimate the value of hydraulic module, it is more appropriate to evaluate effect of loading the mass transfer module. A series of experiments with different thickness of product layer in the mass transfer module of the continuous action MW apparatus was carried out. With a thin layer, contact area of the phases is larger and larger volume of the solvent is in contact with the product, with larger layer of the product, movement of the solvent is complicated, which affects the efficiency of raw material use. Ground coffee with a particle size [0.63, … 1] mm was used for the experiment. Product weight in cartridges was 100, 75, 50 and 20 g. Extraction was performed at a flow rate of the solvent 6.4 kg/h ($1.66 \cdot 10^{-3}$ kg/s) and power of MW radiation of 490 W/h (50 %). Temperature of the extract at inlet is 12…14 °C. Extracted 30.3 g (30.3 % d.s.), 23.4 g (31.2 % d.s.), 16.32 g (32.6 % d.s.) and 8.96 g (35.8 % d.s.).

When choosing thickness of the product layer in the module, it should be taken into account that large layer of the product may interfere with movement of the solvent, and small one will cause a low concentration of solids in the finished extract, which will cause problems of further processing of the extract and inefficient use of energy.

Size of the particles, or dispersion of the raw material, is a factor that determines the specific surface area in contact with the solvent, respectively, it affects the rate of transition of soluble components to the extract. The experiment was carried out using 50 g of ground Arabica coffee variety of grinding. Using a set of laboratory sieves, ground coffee beans were separated by dispersion: [2.5, … 2] mm; [2, … 1] mm; [1, … 0.8] mm; [0.8, … 0.63] mm. Smaller particles were not used due to peculiarities of structure of the mass exchange modules of extractor.

As the particle size of ground coffee decreases, extraction of the extractives from the raw material to the extract increases, this is explained by the increase of contact area of the phases in the solid-solvent system, greater openness of the capillaries containing the

extractives. Large particles of crushed coffee beans are characterized by a slow transition of extractives to the extract.

After processing results obtained values of mass transfer coefficient (fig. 4), depending on speed of movement of the solvent inside the extractor.

When thickness of the ground coffee in mass exchange module is increased by [1.75, ... 4] times, mass transfer coefficient is increased by [1.2, ... 2.5] times, respectively.

Processing of the experimental data set makes it possible to recommend following relation for the calculation of mass transfer intensity during extraction from ground coffee beans under conditions of MW field:

$$St_m = 0.0027 \cdot (Re)^{-0.86}(Sc)^{0.43}(\Pi)^{0.35}(Bu)^{0.42}(D)^{1.2} \quad (5)$$

where St_m Stanton number of mass-transfer; Re Reinolds number; Sc Shmidt number; Π parametrical number; Bu Burdo number; D diffusion coefficient.

Third stage of the experimental studies was carried out on a closed stand with vacuum extraction tank. Fruits and solvent are placed in a volume that is paired with reflux condenser. After loading the volume, system is evacuated and magnetron mode is set. Temperature in the system is provided by a refrigerating machine, vacuum pump and camera magnetron. Reliability of the sealing system, consistency of the capacities of magnetron and refrigerating machine provide the opportunity to conduct the experiment without changes in evacuated system. In the first stage, a comparison of extraction efficiency in a stream without EMF and with EMF and with vacuum MW extractor was carried out. In this series of experiments, the object of research was rose hips. It is known that rose hips are rich in vitamins, in particular is thermo unstable vitamin C, which decomposes at about 60 ° C.

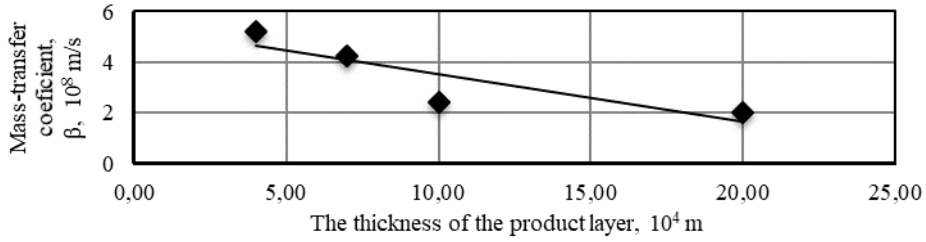

Fig. 4. The dependence of mass transfer coefficient from the product thickness layer.

Experiments were carried out with halves of rose hips under the same temperature conditions. From the dependencies (fig. 5) it can be seen that vacuum is a significant factor in the intensification of mass transfer. Effect of pressure in the chamber on the intensity of extraction was established (fig. 6). With increasing pressure from 15 kPa to 45 kPa, concentration of the extract increased by 25%.

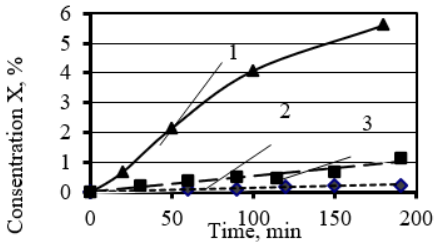

Fig. 5. The dependence of change of dry matter concentrations on extraction duration for different plants: 1 - MW vacuum extractor; 2 - MW extractor stream; 3 - no field in the stream.

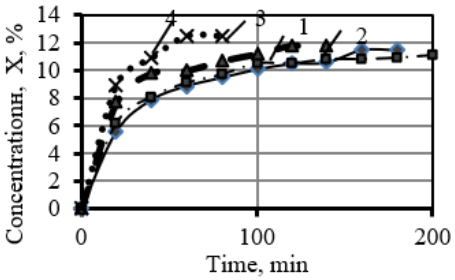

Fig. 6 Effect of pressure on extraction kinetics in vacuum microwave apparatus: 1 – 15 kPa; 2 - 25 kPa; 3 - 30 kPa; 4 - 45 kPa.

With increasing power, intensity of mass transfer increased (fig. 7), but temperature of the process is also increased (fig. 8).

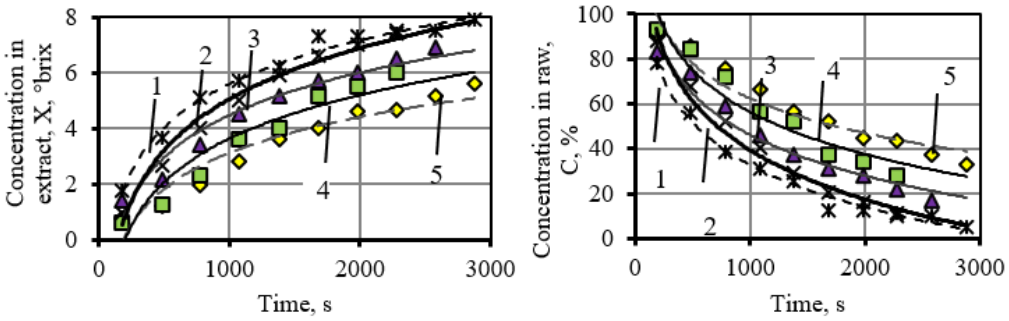

Fig.7. Influence of magnetron power to extraction kinetics: 1 - 1024 W; 2 - 682 W; 3 - 512 W; 4 - 273 W; 5 - 136 W.

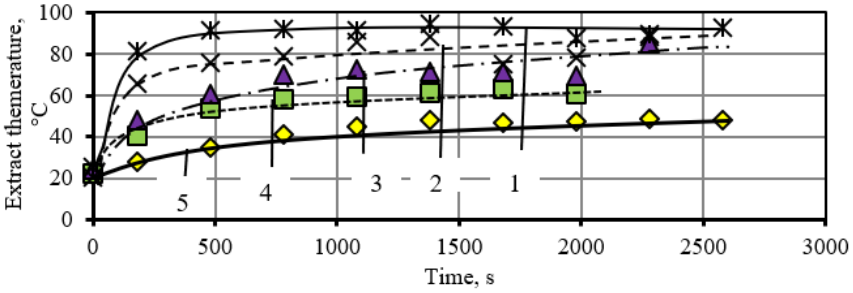

Fig.8. Process thermograms: 1 - 1024 W; 2 - 682 W; 3 - 512 W; 4 - 273 W; 5 - 136 W.

Thus, contradiction between the intensity of extraction and the preservation of vitamin C should be solved, including, on the basis of chemical analysis of samples of extracts. Results of chemical analysis of the samples of concentrated extracts are shown in table 6.

Table 6. Characteristics of extracts and concentrates

Sample	Concentration of d.s., %	Vitamin C content, mg/100 cm^3	Relative vitamin content C, %
Extract	4.,2	[430, … 550]	[10.2, … 13]
Concentrate №1	24	[3,640, … 4,050]	[9.2, … 10.2]
Cryoconcentrate №2	14	[2,120, … 2,310]	[11.2, … 12.5]

It is known that 100 g of rose hips contain an average of [470, ... 2,400] mg of vitamin C, depending on the variety and growing conditions [0.47, ... 2.4%]. *Rosa Cinnamomea* contains more vitamin C than any other species up to 2,400 mg per 100 g. It is determined that content of dry water-soluble extractives for rose hips ranges from [20, ... 25]%. Therefore, relative to the total solids content of vitamin C is [2.1, ... 11]%.

An extract volume in 500 cm^3 was selected for further concentration. When concentrated in MW device, operating temperatures varied in range of [30, … 40] °C. In 10 minutes, 412 cm^3 of moisture was removed from the extract, solids content of the extract was 24%. By cryoconcentration was treated 500 cm^3 of extract. The freezing time of the block amounted to 13 minutes. Separation of the ice block and concentrate gave 160 cm^3 of the extract with a concentration of 12%. Separation lasted 1 hour 18 minutes at temperatures close to 0 °C – phase transition temperature for water. Obtained samples proceed an organoleptic research (fig.9). There are 5 points corresponds to a rich, characteristic rose hips aroma, bright reddish-orange colour, taste without tinges of cooking, with a pronounced sour taste, and homogeneous consistency. Compared to

thermostatic processing at 60 ° C, extraction efficiency in the MW field increases approximately by 1.5 times. Increasing the specific power from 90 to 900 W/kg increases yield of solids by 3 times and significantly reduces duration of the process.

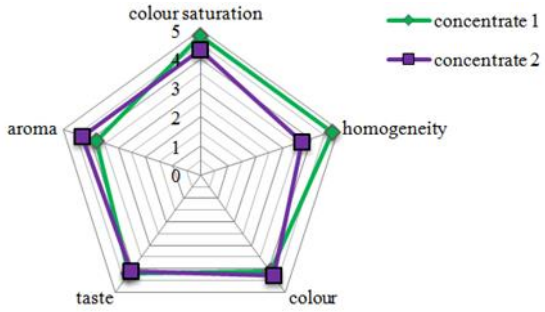

Fig. 9. Profile chart of concentrate quality assessment.

It can be concluded that cryoconcentrate (2) is better in aroma, colour and taste. But, MW treatment allows you to increase productivity without significant loss of product quality.

3. CONCLUSIONS

Influence of the solvent consumption, increase of the equivalent particle diameter, thickness of the layer on the initial concentration of solids in the extract was determined. Coefficients of mass transfer during the variation of the mode parameters are determined: when increasing power from 90 to 900 W/kg, it increases approximately by 10 times, with increasing consumption of the solvent proportionally, with increasing thickness of the layer by 5 times – decreases by about 4 times, with increasing equivalent diameter ratio of 3 to 0,8 coefficient is reduced by 2 times. Results of the experiments are summarized as mathematical models in criteria form.

Effect of temperature and concentration on the value of ascorbic acid is studied. Samples were compared in the range of concentrations from 11 to 60 ° brix and temperatures of [50, … 70] ° C. It was found that ascorbic acid content in extracts decreases with temperatures above 50 ° C. Chemical studies of the samples were carried out: extract (4.2 ° brix), concentrate obtained in MW vacuum apparatus (24 ° brix) and cryoconcentrate (14 ° brix). Content of vitamin C in these samples was, respectively, 500, 4,000 and 2,200 mg per 100 cm^3. It was found that relative to the total solids content of vitamin C in all samples was kept in range of [10.2, ... 13] %. As a result of organoleptic studies, a profile of quality indicators of samples: concentrate and

cryoconcentrate was constructed. The cryoconcentrate has slightly superior indicators in comparison with MW concentrate. But, MW treatment allows to increase productivity without significant loss of product quality.

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