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Kinetics of extraction of phenolic compounds and flavonoids from *Carlina acaulis*

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Abstract. The study of the kinetics of extraction of phenolic compounds and flavonoids from crushed roots of *Carlina acaulis* using 40% and 70% of water-ethanol mixture by infusion method is described in the article. The total value of the mass transfer coefficient and the value of the transfer coefficient through the cell wall, in the intercellular space and the volume of the extractant were determined.

Particles of *Carlina acaulis* roots of different sizes (0.2, 0.3, 0.5 mm) were studied; different concentrations of ethyl alcohol were used - 40% and 70%; the ratio of raw materials: extractant was 1:10.

The analytical dependence of the mass transfer coefficient k and the leaching coefficient A on the solid particle size d and the concentration of the extractant was obtained, which allows to predict the extraction process and to design equipment for the technological process in production.

Kinetic equations of the process of extraction of phenolic compounds and flavonoids from *Carlina acaulis* roots by infusion method are derived. The obtained equations allow to determine the concentrations of phenolic compounds and flavonoids in the extracts at a given point in time with a particle size of the solid phase from 1 to 10 mm, as well as to determine the optimal diameter of the solid phase particles for maximum extraction of the target substance.

Keywords: kinetics, mathematical processing, *Carlina acaulis*, extracts, phenolic compounds, flavonoids

INTRODUCTION

The search for the raw material base of plants with a high content of biologically active compounds (bar) is relevant for use in various industries. An important task is to determine the optimal conditions of the extraction process to obtain the maximum number of bars. One such method for optimization is an experimental study of the extraction kinetics. The study of the kinetic laws of the extraction process will allow to perform technological calculations of processes and devices for the production of a complex of biologically active compounds with a high content of phenolic compounds and flavonoids. The mechanism and kinetics of extraction of BAS from plant raw materials are described in detail in [1-9]. And the mechanisms of extraction of BAS from plant raw materials and even more complex extraction processes were also described in [10-12].

Based on extracts of medicinal plants that contain phenolic compounds and flavonoids, new highly active drugs are created that have anti-inflammatory, anti-carcinogenic, antiviral, antiparasitic or bactericidal activity. Recent studies show that flavonoids can be used in the treatment of various diseases of the internal organs, they are less toxic and more effective than known drugs. Carlina acaulis belongs to the family Asteraceae and is listed in the European Red List. The plant is a valuable medicinal crop and producer of the bar complex. Analysis of the literature indicates bacteriostatic, bactericidal, antioxidant, anti-inflammatory, and antifungal action of *C.acaulis* [13-15]. Phenolic compounds and flavonoids are secondary metabolites of the plant, which are involved in many key processes of plant growth and development.

The extraction process is a mass transfer process associated with the transfer of substances through the surface of a phase contact or through a porous membrane, which is characterized by a certain rate of interfacial interaction. This results in targeted components that are necessary for future use. The extraction process proceeds by diffusion from a medium with a high concentration (solid phase) to a medium with a low concentration (liquid phase) to a state of equilibrium, when the chemical potentials in the two phases are balanced, the same number of molecules pass from the roots of the plant to the extractant as from the extractant in the root. Substances from the internal environment of solid particles (plant root cells) diffuse into the extractant until equilibrium concentrations are reached.

Substances of the internal environment of solid particles from living plant cells pass through the cell wall, a semipermeable partition that does not allow substances dissolved in cell juice to pass out, and the extractant penetrates the cell due to osmosis.

When using dry plant raw materials, substances of the internal environment of solid particles from dead plant cells pass through the cell wall, which has already lost its properties of a semi-permeable septum and passes out substances dissolved in cell juice, and the extractant penetrates the cell, thanks to dialysis [16].

During the extraction of the solid phase (plant cells) into the liquid phase (ethyl alcohol), the process of mass transfer of target substances to the extractant occurs in three stages:

- diffusion of target substances through the cell membrane into the intercellular space;
- diffusion in the intercellular space to the surface of a solid body;
- transition from a solid to the main volume of the extractant [17].

These processes are described by the equation for determining the mass transfer coefficient:

$$k = (\delta/D_c + d/D_m + 1/D_e)^{-1}$$

where D_c is the diffusion coefficient of target substances through the cell shell;

D_m is a diffusion coefficient in the intercellular space to the solid surface;

D_e is a diffusion coefficient to the main volume of the extractant;

δ is a cell wall thickness;

d is the diameter of the solid phase particle.

When infusing, when there is no mixing, the mass transfer coefficient in the volume of the extractant can be ignored, and the equation will have the form:

$$k = (\delta/D_c + d/D_m)^{-1}.$$

Taking into account the total value of the transfer coefficient, the equation will have the form:

$$k = (1/k_c + d/k_m + 1/k_e)^{-1},$$

where *k* is the total value of the mass transfer coefficient;

k_c is a mass transfer coefficient through the cell shell;

k_m is a mass transfer coefficient in the intercellular space;

k_e ia s mass transfer coefficient in the volume of the extractant.

MATERIALS AND METHODS

The roots of *Carlina acaulis* were ground in a laboratory mill and seeded through sieves. Using Sieve analysis, the size of solid particles of dried plant roots was determined, which was 0.2, 0.3 and 0.5 mm. Extraction was performed by infusion in 40% and 70% ethyl alcohol, using a raw material:extractant ratio of 1:10.

The extraction kinetics was studied for 3 days (72 hours). The roots of *Carlina acaulis* crushed in a laboratory mill to a size of 2-3 mm were filled with ethyl alcohol for 3 days, filtered and the resulting extract was used for studies to determine the content of phenolic compounds and flavonoids.

The results of determining the quantitative characteristics of the presence of phenolic compounds and flavonoids were performed according to to known methods. Kinetics studies were performed by infusion in a fixed layer of the extractant for 72 hours.

A suspension of crushed *Carlina acaulis* roots weighing 10 g was loaded into a flask with a capacity of 0.250 liters, an extractant was added in the amount of 0.1 liters for the ratio raw material:extractant – 1:10. 40% and 70% ethyl alcohol were used as an extractant for the extraction of phenolic compounds and flavonoids. The extraction process was carried out at room temperature of 20±2 ° C in a stationary extractant layer. At certain intervals (every 6 hours), the contents of each container were sequentially filtered and determined according to the content of phenolic compounds and flavonoids.

RESULTS AND DISCUSSIONS

The results of experimental studies are presented in tables and figures. The results of studying the kinetics of extraction by infusion of phenolic compounds are presented in Table. 1, flavonoids in Table. 2 and in Fig. 1, 2 in the form of graphs of the dependence of the bar content on time.

The results of the experiment indicate that the equilibrium state during the extraction of crushed roots of *Carlina acaulis* by infusion occurs faster for more crushed raw materials.

TABLE 1. THE CONTENT OF PHENOLIC COMPOUNDS IN THE EXTRACTION OF CRUSHED ROOTS OF *CARLINA ACAULIS* IN ETHANOL BY THE METHOD OF INFUSION

$C_{ethanol}$, %	d, 10^{-3} м	$t_{extraction}$, h												
		1	6	12	18	24	30	36	42	48	54	60	66	72
40	2,0	0,326	0,623	0,812	1,056	1,156	1,254	1,312	1,406	1,43	1,43	1,43	1,43	1,43
	3,0	0,312	0,598	0,714	0,780	0,823	0,920	1,183	1,274	1,38	1,41	1,43	1,43	1,43
	5,0	0,265	0,282	0,312	0,535	0,584	0,645	0,812	0,956	1,165	1,232	1,375	1,38	1,40
70	2,0	0,456	0,815	1,228	1,386	1,425	1,590	1,614	1,642	1,68	1,68	1,68	1,68	1,68
	3,0	0,424	0,644	0,831	0,964	1,189	1,328	1,485	1,595	1,662	1,668	1,68	1,68	1,68
	5,0	0,312	0,356	0,432	0,517	0,673	0,824	1,128	1,384	1,406	1,42	1,42	1,51	1,56

TABLE 2. THE CONTENT OF FLAVONOIDS IN THE EXTRACTION OF CRUSHED ROOTS OF *CARLINA ACAULIS* IN ETHANOL BY THE METHOD OF INFUSION

$C_{ethanol}$, %	d, 10^{-3} м	$t_{extraction}$, h												
		1	6	12	18	24	30	36	42	48	54	60	66	72
40	2,0	0,082	0,145	0,198	0,224	0,237	0,245	0,252	0,276	0,285	0,296	0,320	0,320	0,320
	3,0	0,064	0,142	0,186	0,196	0,205	0,224	0,241	0,265	0,280	0,320	0,320	0,320	0,320
	5,0	0,030	0,096	0,132	0,154	0,176	0,195	0,217	0,227	0,262	0,285	0,305	0,318	0,320
70	2,0	0,095	0,154	0,204	0,275	0,346	0,386	0,408	0,415	0,420	0,425	0,425	0,425	0,425
	3,0	0,090	0,148	0,215	0,285	0,342	0,356	0,389	0,405	0,415	0,420	0,422	0,425	0,425
	5,0	0,078	0,143	0,190	0,232	0,262	0,272	0,278	0,318	0,345	0,361	0,386	0,395	0,420

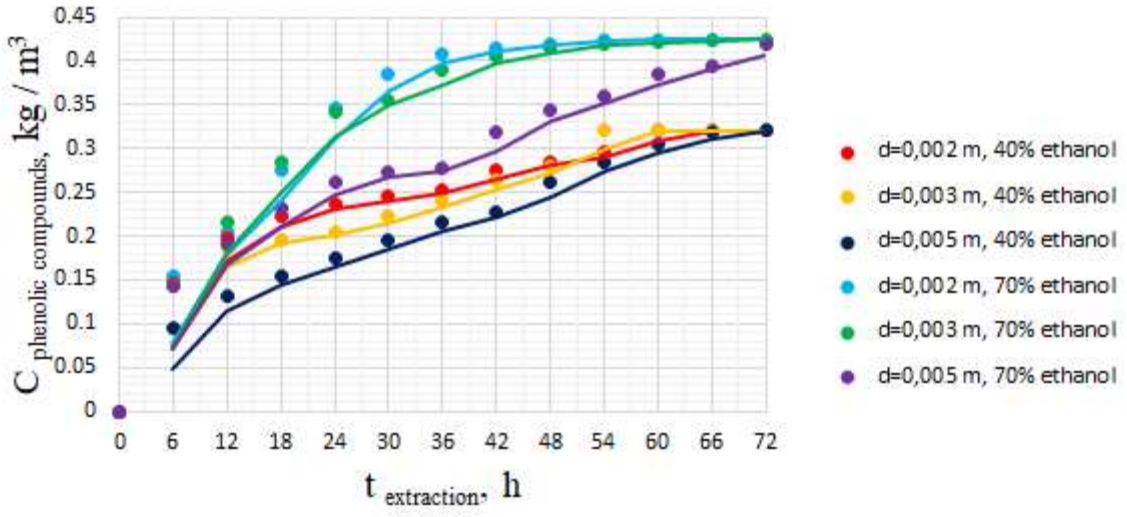

Fig. 1. Dependence of the concentration of phenolic compounds on the extraction time of 40% and 70% water-ethanol mixture by infusing dried and crushed to different sizes roots of *Carlina acaulis*

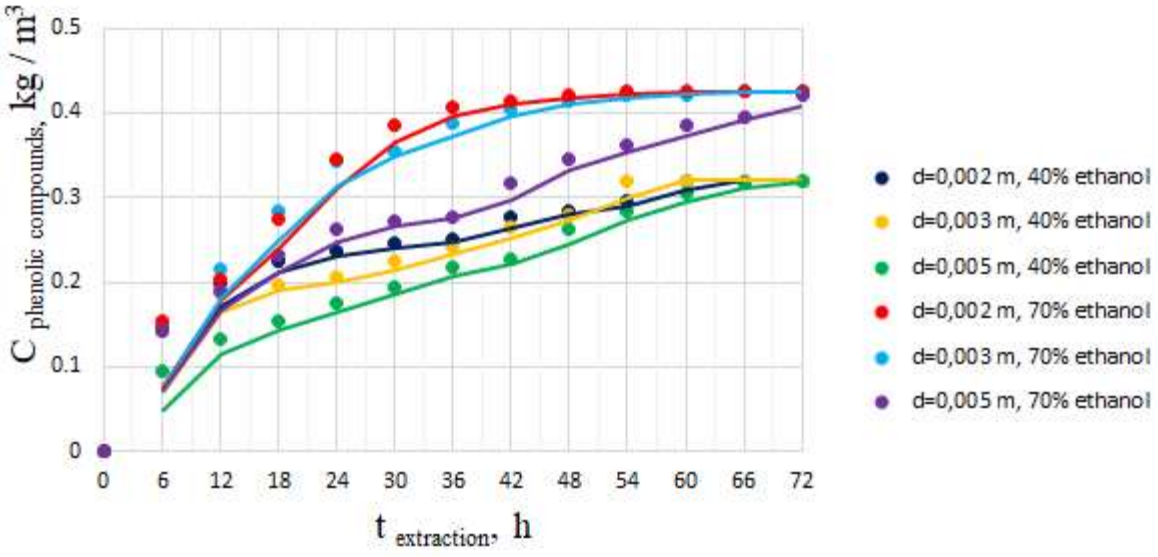

Fig. 2. Dependence of the flavonoid concentration on the extraction time of 40% and 70% water-ethanol mixture by infusing dried and crushed roots of *Carlina acaulis* to different sizes

Namely, for raw materials with a particle size of 2 mm, the equilibrium concentration of phenolic compounds when using a 40% ethanol-water mixture is reached in 48 hours and is 1.43 kg/m^3, while for particles with a size of 3 mm it is reached in 54-60 hours and is 1.43 kg/m^3, and for the largest particles of 5 mm it is reached in 72 hours.

When using a 70% ethanol-water mixture, we observe higher results, namely, the equilibrium concentration of phenolic compounds is reached after 48 hours and is 1.68 kg/m^3, while for particles of 3 mm in size it is reached after 54-60 hours, and for the largest

particles of 5 mm it is reached after 72 hours.

From the results of the study shown in Fig. 1 it can be seen that a maximum concentration of 1.43 kg/m^3 is observed for particles of 2-3 mm in size after 72 hours of extraction using a 40% ethanol-water mixture. And the maximum concentration of 1.68 kg/m^3 when using a 70% ethanol-water mixture is also observed for particles of 2-3 mm in size after 72 hours of extraction .

There is also a dependence of the content of phenolic compounds in the extract on the concentration of the extractant. From the results of the study presented in Table. 1. and in Fig. 1. it can be seen that higher results of the content of phenolic compounds were obtained when using 70% ethyl alcohol than when using 40% ethyl alcohol.

From the results of the study shown in Fig. 2 and Table. 2. it can be seen that the equilibrium concentration of flavonoids is reached in 60-66 hours for particles of 2-3 mm in size when used as an extractant of 40% ethyl alcohol and 54 hours when used as an extractant of 70% ethyl alcohol.

From the results of the study shown in Fig. 2, it can be seen that a maximum concentration of 0.425 kg/m^3 is observed for particles of 2-3 mm in size after 72 hours of extraction in 70% ethyl alcohol. And when extracted in 40% ethyl alcohol, the maximum concentration of 0.320 kg/m^3 is also observed for particles of 2-3 mm in size after 72 hours.

The dependence of the flavonoid content in extracts also depends on the concentration of the extractant. From the results of the study presented in Table 2. and in Fig. 2. it can be seen that higher results of flavonoid content were obtained when using 70% ethyl alcohol than when using 40% ethyl alcohol.

MATHEMATICAL PROCESSING OF THE RESULTS OF EXPERIMENTAL STUDIES OF THE PROCESS OF EXTRACTION OF PHENOLIC COMPOUNDS AND FLAVONOIDS FROM *CARLINA ACAULIS* BY INFUSION

When studying the kinetics of the process of extracting substances from the solid phase of plant raw materials, it is important that the plant is a living object, the basis of which is a cell that actually contains these substances. First, the target substance passes through the cell wall into the intercellular space, then diffusion occurs in the intercellular space to the interface of the phases – the surface of the particle. This is taken into account when constructing mathematical models.

Therefore, certain designations are used: C_{ts} – concentration of the target substance (phenolic compounds / flavonoids) contained inside the cell, in its internal space; V_c – cell volume, a constant value that does not depend on the contents of the bar inside the cell; t – time; C_1 – the concentration of the target substance (phenolic compounds / flavonoids) contained in the volume of the extractant is much less than the concentration in the cell space; a solid particle of plant raw materials consists of a large number of cells and is taken as a ball.

Therefore the following mathematical model of this process is proposed [18, 19]:

The first equation of the system describes the change in the concentration of the target substance in the cell volume over time:

$$\frac{dC_c}{dt} = -k_c(C_c - C)$$

The second equation describes the change in the concentration of the target substance in intercellular space over time:

$$\frac{dC}{dt} = k_c(C_c - C) - k_M(C - C_c)$$

The third equation is the material balance equation.

$$V_\varepsilon C_{ts} = V_\varepsilon C_c + V(1-\varepsilon)C + WC_1$$

where k_c is a coefficient of mass transfer through the cell wall; W is a volume of the extractant; k_M is a coefficient of mass transfer in the intercellular space to the surface of the solid particle (phase); V is a volume of the extractant contained in the free space of the solid particle (phase), in the cell and the intercellular space; ε is a porosity of the raw material layer.

A mathematical model is a system of these three equations with given initial and boundary conditions. Solving a mathematical model describes:

1) changes in the concentration of the target substance C_C in the cell volume over time, provided thatt = 0, C = 0, $C_c = C_{ts}$:

$$C_c = C_{ts}e^{-k_c t},$$

where $k = \frac{D_c F_c}{\delta_c V_c} = \frac{D_c}{\delta_c R_{eq}}$,

where δ_c is a cell wall thickness, R_{eq} is an equivalent cell radius.

2) changes in the concentration of intracellular substance C in the intercellular environment over time, provided that t = 0, C = 0:

$$C_c = C_{ts}\frac{k_c}{k_M - k_c}\left[e^{-k_c t} - e^{-k_M t}\right],$$

where $k_M = \frac{D_M F_M}{dV_M} = \frac{D_M}{dR_M}$,

where d is the size of the extracted particle, R_M is the radius of the extracted particle.

3) changes in the concentration of the target substance in the main volume of the extractant under the condition of intensive mixing, for example, in an apparatus with a stirrer, if in a state of equilibrium $C_1 = C_c = C = C_{1p}$:

$$C_1 = C_{1p}\left(1 - \frac{1}{r+1} exp - (k_M - k_c)t\right)$$

or

$$\left(1 - \frac{C_1}{C_{1p}}\right) = A \exp(-kt),$$

where k = k_M – k_c = $\frac{D_M\delta - D_c d}{\delta_c d}$; $A = \frac{1}{1+r}$, afterwards, kinetic constants determined based on experimental data were used.

The kinetics of the extraction process is described by the equation:

$$C = C_p(1 - Ae^{-kt}) \qquad (1)$$

where C is an instant concentration of target components in the extract, C_p is an equilibrium concentration of target products in the extract, A is a logarithmic steel (leaching coefficient), k is a mass transfer coefficient,t is a extraction time.

Ae^{-kt}a small number that can be ignored when t = $t_p = \infty$, C = C_p , t_p– time to reach equilibrium.

Equation (1) logarithm and obtain an equation of the form:

$$\ln\left(1 - \frac{C1}{C1p}\right) = \ln(A) - kt$$

According to the graph (fig. 1.) in semi-logarithmic coordinates$\ln\left(1 - \frac{C1}{C1p}\right)$-f(t,d) we get a straight line that can be used to determine A i k. In the figure, we observe two extraction periods – irregular and regular. The first period indicates the process of washing out target substances from destroyed cells. And the linear dependence in the second period reflects the process of diffusion of substances from plant raw materials into the extractant. If we assume that there are no destroyed cells in the raw material and extraction occurs from the whole raw material, then we will continue the straight line to the coordinate axis and get a "dependence on the ideal case". When raw materials are crushed, cells are destroyed and the curve shifts by an amount equal to the leaching coefficient A. The mass transfer coefficient k is determined from the graphs (fig. 1, 2) as the tangent of the slope angle k = tg(α).

When using infusion as an extraction method, it is necessary to pay attention to the mass transfer of substances from the surface of the material to the extract, and the resistance of the diffusion boundary layer should not be neglected. The extractant is stationary above the surface of the solid particle (phase), but minor convective displacements are still present and depend on the temperature, viscosity, and density of the extractant.

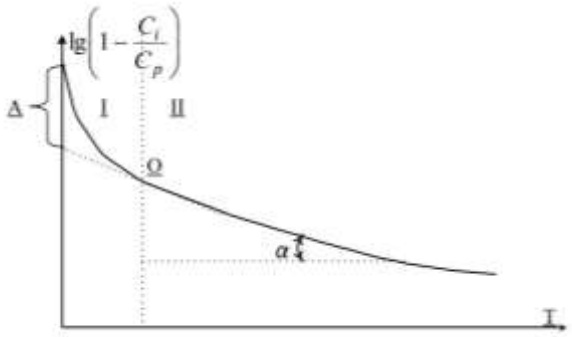

Fig. 3. Graphoanalytical calculation leaching and mass transfer coefficients

The calculation was made$\ln(1 - \frac{C1}{C1p})$ at different time points, when extracting phenolic compounds and based on the data, the dependence is constructed$\ln(1 - \frac{C1}{C1p})$= f (t). The results are presented in Table. 3 and in Fig. 4 the obtained dependence makes it possible to determine the leaching coefficient and the total mass transfer coefficient k for each value of the solid particle size (phase) from 2 to 5 mm and at different extractant concentrations – 40% and 70%. The results $\ln(1 - \frac{C1}{C1p})$at different time points, t for the extraction of phenolic compounds is shown in Table. 3.

The results of $\ln(1 - \frac{C1}{C1p})$ at different time points, t for flavonoid extraction is presented in Table. 4.

According to the data presented in Table. 3, 4 dependencies are constructed $\ln(1 - \frac{C1}{C1p})$ = f(t) and approximated by linear functions. The leaching coefficient A and the total mass transfer coefficient k of phenolic compounds and flavonoids from *Calendula acaulis* root extracts were also determined.

The equation of a linear function for the particle size can be written as$y_i = \ln(1 - \frac{C_i}{C_{1p}})$

TABLE 3. VALUE OF $\ln\left(1 - \frac{C1}{C1p}\right)$ AT DIFFERENT POINTS IN TIME T FOR THE EXTRACTION OF PHENOLIC COMPOUNDS WITH ETHANOL OF VARIOUS CONCENTRATIONS FOR DIFFERENT DIAMETERS OF VEGETABLE RAW MATERIALS BY THE INFUSION METHOD

$C_{extragent}$, %	d, 10^{-3} m	Time, h						
		1	**6**	**12**	**18**	**24**	**30**	**36**
40%	**2,0**	-0,259	-0,573	-0,839	-1,341	-1,652	-2,095	-2,495
	3,0	-0,246	-0,542	-0,692	-0,789	-1,241	-1,485	-1,756
	5,0	-0,210	-0,225	-0,352	-0,631	-0,942	-1,270	-1,864
70%	**2,0**	-0,317	-0,664	-1,313	-1,743	-2,325	-2,927	-4,624
	3,0	-0,291	-0,483	-0,683	-0,853	-1,230	-1,563	-2,154
	5,0	-0,223	-0,259	-0,324	-0,403	-0,565	-0,751	-1,284

TABLE 4. THE VALUE OF $\ln(1-\frac{C1}{C1p})$ AT DIFFERENT POINTS IN TIME T FOR THE EXTRACTION OF FLAVONOIDS WITH ETHANOL OF VARIOUS CONCENTRATIONS FOR DIFFERENT DIAMETERS OF VEGETABLE RAW MATERIALS BY THE INFUSION METHOD

$C_{extragent}$, %	d, 10^{-3} m	Time, h						
		1	**6**	**12**	**18**	**24**	**30**	**36**
40%	**2,0**	-0,296	-0,604	-0,964	-1,204	-1,349	-1,451	-1,549
	3,0	-0,223	-0,587	-0,870	-0,948	-1,023	-1,204	-1,399
	5,0	-0,098	-0,357	-0,532	-0,656	-0,799	-0,940	-1,136
70%	**2,0**	-0,253	-0,450	-0,654	-1,041	-1,683	-2,389	-3,219
	3,0	-0,238	-0,428	-0,705	-1,110	-1,633	-1,818	-2,469
	5,0	-0,205	-0,416	-0,602	-0,804	-0,978	-1,043	-1,084

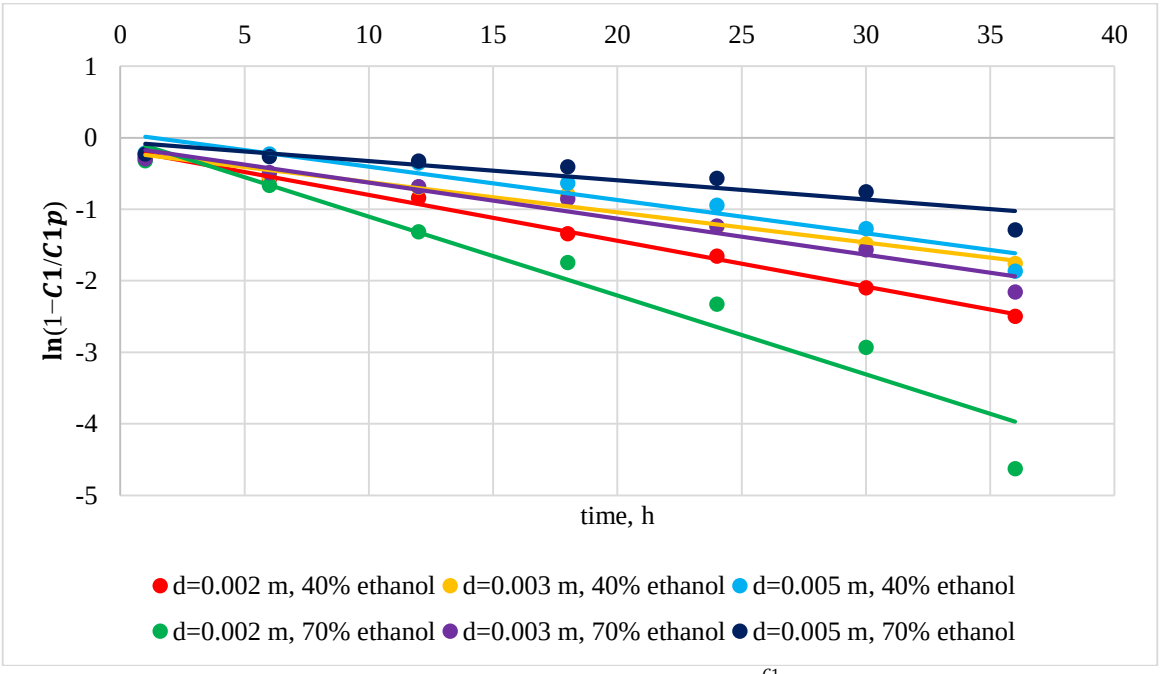

Fig. 4. Logarithmic dependence of changes in the concentration of phenolic compounds$\ln(1-\frac{C1}{C1p})$from time to time, when extracting 40% and 70% ethyl alcohol for different particle sizes of *Carlina acaulis* roots by the infusion method.

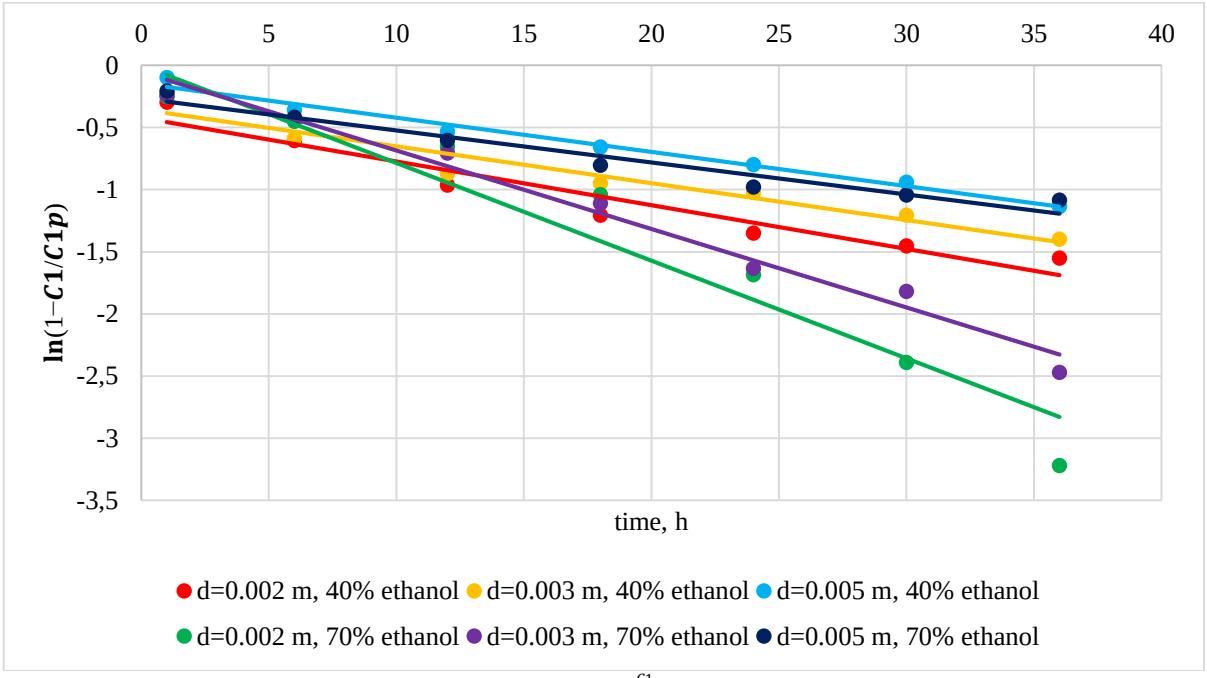

Fig. 5. Logarithmic dependence of changes in flavonoid concentration$\ln(1-\frac{C1}{C1p})$ from time to time, when extracting 40% and 70% ethyl alcohol for different particle sizes of *Carlina acaulis* roots by te infusion method.

Based on the dependencies obtained in Fig. 4 and 5, systems of equations for phenolic compounds (2, 3) and flavonoids (4, 5) are obtained, which describe approximate logarithmic lines in the second extraction period, which makes it possible to accurately determine the mass transfer coefficient.

For 40% : $y_1 = -0{,}000068 \cdot t - 0{,}11054$

$y_2 = -0{,}000046 \cdot t - 0{,}10672$ (2)

$y_3 = -0{,}000025 \cdot t - 0{,}08683$

for 70%: $y_1 = -0{,}000073 \cdot t - 0{,}12342$

$y_2 = -0{,}000054 \cdot t - 0{,}11707$ (3)

$y_3 = -0{,}000032 \cdot t - 0{,}09543$

for 40% : $y_1 = -0{,}000054 \cdot t - 0{,}11023$

$y_2 = -0{,}000047 \cdot t - 0{,}09521$ (4)

$y_3 = -0{,}000019 \cdot t - 0{,}08592$

for 70%: $y_1 = -0{,}000069 \cdot t - 0{,}12054$

$y_2 = -0{,}000051 \cdot t - 0{,}11344$ (5)

$y_3 = -0{,}000028 \cdot t - 0{,}09302$

Using the basic extraction equation and determining the mass transfer coefficient k and the leaching coefficient a, we described the change in the concentration of phenolic compounds and flavonoids as a function of time using mathematical expressions (table. 5, 6).

TABLE 5. KINETIC CONSTANTS OF THE PROCESS OF EXTRACTION OF PHENOLIC COMPOUNDS FROM THE ROOTS OF *CARLINA ACAULIS* BY INFUSION IN 40% AND 70% ETHYL ALCOHOL

	40%			**70%**		
d, mm	2,0	3,0	5,0	2,0	3,0	5,0
k, 10^{-4} 1/s	3,4	3,2	2,4	3,5	3,4	2,8
A	-0,913	-0,925	-0,942	-0,926	-0,954	-0,962

Since the mass transfer coefficients depend on the diameter, it is possible to represent the dependence $k = f(d)$ and describe the equations for the extraction of phenolic compounds and flavonoids:

$$k = -0{,}3685 \cdot 10^{-5} d + 7{,}0895 \cdot 10^{-5} \quad (6)$$

$$k = -0{,}3265 \cdot 10^{-5} d + 6{,}5329 \cdot 10^{-5} \quad (7)$$

TABLE 6. KINETIC CONSTANTS OF THE FLAVONOID EXTRACTION PROCESS FROM THE ROOTS OF *CARLINA ACAULIS* BY INFUSION IN 40% AND 70% ETHYL ALCOHOL

	40%			**70%**		
d, mm	2,0	3,0	5,0	2,0	3,0	5,0
k, 10^{-4} 1/s	3,0	2,6	2,2	3,2	3,1	2,6
A	-0,882	-0,888	-0,913	-0,934	-0,962	-0,975

Since the leaching coefficients depend on the diameter, we can represent the dependence A=f(d) and describe it by the equation for determining the leaching coefficient a for the extraction of phenolic compounds (8) and flavonoids (9). Thus, leaching coefficients are obtained depending on the particle size of vegetable raw materials:

$$A = 0{,}0064 \cdot 10^{-4} d + 0{,}8925 \quad (8)$$

$$A = 0{,}0068 \cdot 10^{-4} d + 0{,}8789 \quad (9)$$

The obtained equations allow you to determine the concentration of phenolic compounds and flavonoids at any time t, at a given particle size of the solid phase, or perform the reverse operation: calculate the required particle size of the solid phase to achieve an equilibrium concentration in a given time.

Substituting (6-9) into equation (1) we obtain the final kinetic equations to determine the concentration of the target extraction products depending on the particle size of the solid phase and time:

- for the process of extraction of phenolic compounds:

$$C = C_p(1 - (0{,}0064 \cdot 10^{-4} d + 0{,}8925) \cdot \exp(-(7{,}0895 \cdot 10^{-5} - 0{,}3685 \cdot 10^{-5} d) \cdot t$$

- for the process of extraction of flavonoids:

$$C = C_p(1 - (0{,}0068 \cdot 10^{-4} d + 0{,}8789) \cdot \exp(-(6{,}5329 \cdot 10^{-5} - 0{,}3265 \cdot 10^{-5} d) \cdot t$$

CONCLUSIONS

The kinetics of extraction of total phenols and flavonoids from *Carlina acaulis* roots was studied. The total value of the mass transfer coefficient k by extraction by infusion is 10^{-4} 1/s, during infusion k has a lower order of 10^{-5} 1/s, the value of the mass transfer coefficient through the cell wall k_s 10^{-4} 1/s, mass transfer coefficients in the intercellular space k_m 10^{-4} 1/s and in the volume of extractant k_e 10^{-5} 1/s.

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