

Досліджено вплив поверхнево-активних речовин (ПАР) на зміну фізичних характеристик екстрагентів групи органопрепаратів (хонсуриду, гепарину, ронідази). Встановлені раціональні концентрації ПАР в екстрагентах, за яких досягається мінімум коефіцієнта поверхневого натягу та зменшення динамічного коефіцієнта в'язкості. Обчислені середні товщини приповерхневого ламінарного шару. Дослідженнями кінетики екстрагування підтверджено збільшення виходу екстракту при застосуванні ПАР у екстрагентах. Доведено доцільність використання поверхневого числа

Ключові слова: коефіцієнт поверхневого натягу, середня товщина приповерхневого ламінарного шару, поверхневе число

Исследовано влияние поверхностно-активных веществ (ПАВ) на изменение физических характеристик экстрагентов группы органопрепаратов (хонсурида, гепарина, ронидазы). Установлены рациональные концентрации ПАВ в экстрагентах, при которых достигается минимум коэффициента поверхностного натяжения и уменьшение динамического коэффициента вязкости. Вычислены средние толщины приповерхностного ламинарного слоя. Исследованиями кинетики экстрагирования подтверждено увеличение выхода экстракта при применении ПАВ в экстрагента. Доказана целесообразность использования поверхностного числа

Ключевые слова: коэффициент поверхностного натяжения, средняя толщина поверхностного ламинарного слоя, поверхностное число

INFLUENCE OF SURFACE ACTIVE SUBSTANCES ON THE INTENSIFICATION OF EXTRACTION WHEN CHANGING HYDRODYNAMIC INDICES OF THE TECHNOLOGY OF ORGANOPREPARATIONS

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1. Introduction

Modern development of industries sets the task to intensify technological processes with the use of energy efficient technologies. In recent years, pharmaceutical preparations of natural origin have attracted great interest. They include organopreparations, which are produced from secondary raw materials from meat packing plants. Such materials include cartilages of nose and trachea, lungs, testicles, eyes and spleens of slaughtered animals. Selling such raw material allows meat processing companies to get additional profits.

The technology of organopreparations is rather complicated, therefore it is energy consuming. Improvement of technological processes of organopreparation production with the use of energy efficient technologies remains today's relevant issue.

Raw materials are valuable because the ratio of secondary raw material products for organopreparations to the

mass of slaughtered animals is relatively low. The rational use of raw and energy resources and the required combination of technological and operational parameters significantly influence the formation of prices for finished product.

The most important stage in the production of organopreparations is mass exchanging processes, namely the extraction of relevant substances. Intensification of extraction in the production of organopreparations allows increasing the output of the finished product without any significant additional costs, namely energy.

The promising methods of intensification of mass exchange processes, which are used in modern technological schemes of national economy, involve changes in hydrodynamic parameters of the system. Taking into account these characteristics of mass exchange processes in the system solid body – liquid allows considering the issue of intensification under condition of changing the contact of phases in this system.

2. Literature review and problem statement

A sufficient number of methods are used for the intensification of extraction. The most common ones include increasing the capacity of mass exchanging equipment, geometrical changes in mass exchanging machines, boiling under vacuum, and reducing the average diameter of crushing. It should be noted that the proposed methods require additional capital investments. Thus, for example, in extractors with mixers, the rotation speed of mixing devices is increased [1]. In mass exchange machines, the working volumes are often increased, which is also costly for manufacturers since they need to attract additional funds to improve the equipment [2, 3]. Suggested ways of intensification with the use of vacuuming in the process of extraction require expenses to create the vacuum [4]. When using this approach, the intensification of the process involves the destruction of the near-surface laminar layer surrounding a solid particle in the system solid body – liquid. Such changes can be achieved by decreasing the near-surface laminar layer [5].

In recent years, for the intensification of technologies where extraction is the main process, physical methods, such as low-frequency and high-frequency vibration [6], ultrasonic and combined methods of low-frequency oscillations, have been used [7]. Creation of the proposed methods of intensification requires significant costs which would significantly affect price of the finished product and profitability of production.

To intensify the process of extraction, a temperature increase is believed to be an effective method [8]. Such organopreparations as chonsurid, heparin, and ronidase belong to thermolabile substances. Classic technologies of these products imply conducting the extraction at temperature not exceeding 18 °C [9].

For the extraction of vegetable raw materials, super-critical solutions, in particular carbon dioxide, are used [10]. Such methods of extraction are used in the process of developing technologies for medical preparations, such as nano- and microforms, applying super-critical fluids to obtain them [11]. Super-critical solutions are used when obtaining hard-soluble substances [12–14].

Carrying out the extraction of substances of organopreparations at higher temperatures is not appropriate because there is a possibility of obtaining products of questionable quality.

Extraction implies four stages of the process: penetration of an extractant into the pores of vegetable raw materials, dissolving the target component by an extractant, diffusion transfer of extracted substances to the surface of the particle of crushed raw materials or the particle of extractant, transfer from the surface of the particles through the near-surface laminar layer into the solution of an extractant. Because the raw materials for the production of organopreparations are organic of animal origin, the first two stages of the extraction are missing and the main stage is considered to be the transition of the target component through the near-surface laminar layer [15]. A decrease in this index can positively influence the intensification of extraction and the technology as a whole. An increase in the output of the target component during the extraction can be provided through a decrease in the average thickness of the near-surface laminar layer δ , which occurs around the crushed particle of raw materials in its turbulent deposition. In the near-surface

laminar layer, 98 % of the entire diffusion resistance of the system solid body-liquid is concentrated.

At the interface of two phases, a near-surface laminar layer is formed, in which there is a force field that influences elementary volume of liquid, altering its flow. The force field in the near-surface laminar layer is described by the forces of surface tension. Surface number describes the ratio of the forces of surface tension to the forces of inertia in the near-surface laminar layer [19]. A determining parameter of intensification of the process of extraction of substances of the examined organopreparations is the surface number. It should be noted that the hydrodynamic indices of extractants in the mass exchange processes when manufacturing organopreparations are hardly taken into account at the production site. Such approach is up-to-date and has enough advantages compared to the traditional methods of production of organopreparations from natural sources. Accordingly, the selection of extractants with such physical indicators, which would contribute to hydrodynamic changes in the process, is relevant.

Positive changes in physical indices of extractants in the course of production of organopreparations can be achieved by the introduction of surfactants to extractants [5]. An important task of intensification of the technology of organopreparations is considered to be the creation of conditions under which the extract output will be maximal while energy consumption will be minimal.

A change in hydrodynamic indices of the system [19] at present is one of the most effective ways of the extraction intensification.

3. The aim and tasks of the study

The aim of the work is the study of influence of surface active substances on the increase in efficiency of extraction of substances of organopreparations and conducting comparative assessment of hydrodynamic situation of the process based on dimensionless complex of the surface number.

To achieve the set goal, the following tasks should be solved:

- to determine physical properties of liquid-phase media of extractants (coefficient of surface tension, coefficient of dynamic viscosity, cosine of angle of wetting, density);
- to establish rational concentrations of surfactants (SAS) in an extractant, at which coefficient of surface tension is minimal;
- to determine mean thickness of the near-surface laminar layer in the process of extracting a group of organopreparations by industrial extractants and by the proposed extractants with the addition of SAS;
- using the regularities of kinetics of extraction of organopreparations, to establish effect of adding rational concentrations of SAS on the intensification of the process and on the increase in the output of extracts.

4. Materials and methods of study

During the studies, we used crushed secondary raw material, namely trachea and nasal cartilages of slaughtered animals (horned cattle), lungs and testicles of horned cattle and industrial solutions of extractants. Industrial extract-

ant for the production of chonsurid is the 25 % solution of potassium chloride in the 1 % solution of carbon potassium. Industrial extractant for the production of heparin is the 5 % solution of sodium chloride NaCl (table salt). Industrial extractant of ronidase is saline solution (namely, the 0,9 % solution of sodium chloride) with the addition of 0,25 % of chloroform.

Determination of coefficient of surface tension

The value of coefficient of surface tension for the solutions, which are extractants in the production of chonsurid and heparin, was determined by the method of drop weighing [15]. The value of coefficient of surface tension was calculated by formula: $\sigma = Q / 2\pi r$, where σ is the coefficient of surface tension, N/m; Q is a drop weight, kg; r is the radius of pipette used for dropping the extractant, m.

The drop mass was defined by the following formula: $Q = Q_n / n$, where Q_n is the total mass of drops, kg 10^{-6} ; n is the number of drops.

From a pipette with the diameter of 1 mm, we dropped 10 drops of the industrial solution of extractant for the production of chonsurid (the 25 % solution of KCl in the 1 % solution of K_2CO_3). The mass of ten drops is $0,302 \cdot 10^{-6}$ kg, accordingly, the average mass of one drop of the salt solution of 25 % KCL in the 1% solution of K_2CO_3 is $0,0302 \cdot 10^{-6}$ kg.

Butanol in different concentrations was added to the industrial extractants of heparin and chonsurid as a surfactant. Then the average drop mass for the proposed solutions and their coefficient of surface tension were determined [16].

The magnitude of coefficient of surface tension for the extractant, which is used in the production of ronidase, was determined by the method of maximum pressure by bubbles (the Reh binder method) (Fig. 1) [20].

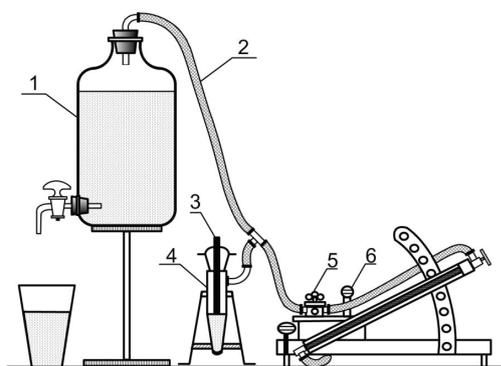


Fig. 1. Scheme of plant for determining surface tension by the Reh binder method: 1 – aspirator; 2 – connecting tube; 3 – capillar; 4 – cell; 5 – three-way vent; 6 – regulator of level of manometric liquid

In a measuring flask, the salt solution is prepared for 100 ml. 8–10 solutions with the addition of SAS are prepared by the liquefaction method.

The method is based on the measurement of pressure, at which the separation of a gas vial, blown out from the capillary into the liquid, takes place.

To determine coefficient of surface tension, the relative method is used. To do this, constant of a capillary (cell) is found, which is determined by the value of maximum pressure p_{H_2O} of the surface tension σ_{H_2O} :

$$k = \sigma_{H_2O} / p_{H_2O}$$

where σ_{H_2O} is the surface tension of water, (reference data at temperature during the study); p_{H_2O} is the height of manometric liquid of the sloping manometer.

Having measured pressure p_{max} for the examined solution, the value of surface tension is calculated by formula:

$$\sigma_n = k \cdot p_{max}$$

where p_{max} is the maximum pressure at which a drop of the examined solution is separated.

Measuring p_{max} is conducted in the following way: the studied liquid is poured into the cell up to the level, at which the end of the capillary is immersed in it for not more than 1 mm. During the immersion of the capillary into the liquid (its contact with the liquid), a meniscus around the end of the capillary is formed, which is its sufficient immersion depth. The cell is fixed to the tripod in vertical position, connected by a flexible branch tube with the aspirator and the manometer vent. For liquefaction, the vent of the aspirator is opened and dropping of the liquid into a glass at the rate of roughly 20–30 drops per minute is reached. At the end of a capillary, a vial of air is formed, which after reaching p_{max} is separated from the capillary and moves to the surface of the liquid and cracks. At this point, the pressure in the system decreases and the manometric liquid drops at some value of p_{max} . In the process of formation of a new vial, the liquid gradually rises again to the maximum value of p_{max} . The level of liquid in manometric tube fluctuates all the time, reaching its maximum value at the moment of the vial separation. If the readings of manometer do not change for 2–3 minutes, these values are considered balanced and are recorded [17].

Determination of dynamic coefficient of viscosity

Dynamic coefficient of viscosity of extractants is determined using the Arrhenius device. Working formula for its calculation is:

$$\mu = \frac{\pi \rho g d^4 \tau}{128 W l} \left(1 + \frac{h}{2} \right)$$

where ρ is the liquid density, kg/m³; t is the time of flowing, s; W is the volume of the liquid, m³ [17].

Determination of mean thickness of near-surface laminar layer

Mean thickness of the near-surface L-layer that is formed around a solid particle in “the system solid body – liquid” is found by technique [5].

We determine the Archimedeian number:

$$Ar = \frac{g \cdot d^3 \cdot (\rho_p - \rho_c) \cdot \rho_c}{\mu^2}$$

where d is the average diameter of the crushed particle, m; ρ_p is the density of the solid raw material, kg/m³; ρ_c is the density of extractant, kg/m³; μ is the dynamic coefficient of viscosity, Pa·s.

Factor of the separation capacity of extractant:

$$F_c = \omega^2 \cdot D / 2 \cdot g$$

where ω is the rotation frequency of the mixer, s⁻¹; D is the diameter of the bottom of the mixer, m.

The modified Archimedean number: $Ar_m = Ar \cdot F_c$. Turbulisation coefficient of laminar film for the transitional mode of deposition:

$$F_c = \frac{0,152 \cdot (\psi \cdot Ar_M)^{0,715}}{2},$$

where ψ is the coefficient of the form of the particles. Mean thickness of the near-surface laminar layer:

$$\delta = \frac{\sqrt{9,42 \cdot \sigma \cdot \cos\theta}}{F_c \cdot g(\rho_p - \rho_c)},$$

where σ is the coefficient of surface tension, N/m; $\cos\theta$ is the boundary angle of wetting. Hydrophilicity of raw material is the index which is described by the boundary angle of wetting [17].

Determination of the surface number

The surface number is calculated by formula [14]:

$$P = \frac{2\pi\sigma\cos\theta}{V_x^2\delta\rho},$$

where σ is the coefficient of surface tension, N/m; $\cos\theta$ is the boundary angle of wetting; V_x is the speed in near-wall layers, m/s; ρ is the density of medium, kg/m³; δ is the average thickness of the near-surface laminar layer, m 10⁻³.

5. Results of studying the influence of SAS on industrial extractants

For the study we selected a group of organopreparations, which are extracted by the salt solutions, namely chonsurid, heparin, ronidase.

A decrease in the coefficient of surface tension in the extraction of chonsurid will take place when adding butanol of mass concentrations of 0,03 % by weight, 0,04 % by weight. The minimum coefficient of the surface tension of extractant of chonsuride will be achieved when adding up to 10 ml of the industrial solution of 0,05 ml of butanol alcohol, that is, 0,05 % by weight. In this case, butanol alcohol is used as SAS. When adding larger mass concentration, surface tension coefficient gradually increases. Such changes are explained by the fact that at the concentration of 0,05 % by weight of butanol, critical concentration of micelle-formation is created on the surface of the solution, that is why surface tension is minimal. An increase in the coefficient of surface tension at the concentrations of 0,06 % by weight and 0,07 % by weight occurs due to the fact that the industrial extractant contains sufficient concentration of salt.

A significant decrease in the value of dynamic coefficient of viscosity is observed when adding 0,05 % by weight of butanol to the industrial extractant of chonsurid (Fig. 2).

A study of determining boundary angle of wetting revealed that an increase in this index occurs with the 0,05 % by weight concentration of butanol in the extractant of chonsurid (Fig. 3). Boundary angle of wetting of the industrial extractant was determined by adding butanol in the concentrations of 0,03–0,07 % by weight. The magnitude of

boundary angle of wetting depends on coefficient of surface tension (Fig. 3).

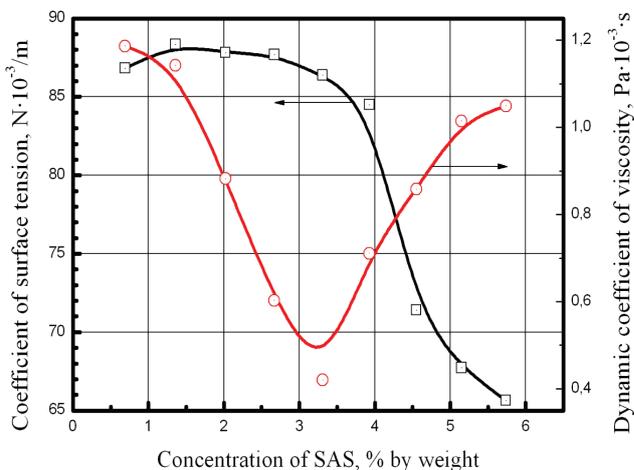


Fig. 2. Change in coefficient of surface tension and coefficient of dynamic viscosity when adding different mass share of butanol to industrial solution; 1 – coefficient of surface tension, 2 – dynamic coefficient of viscosity

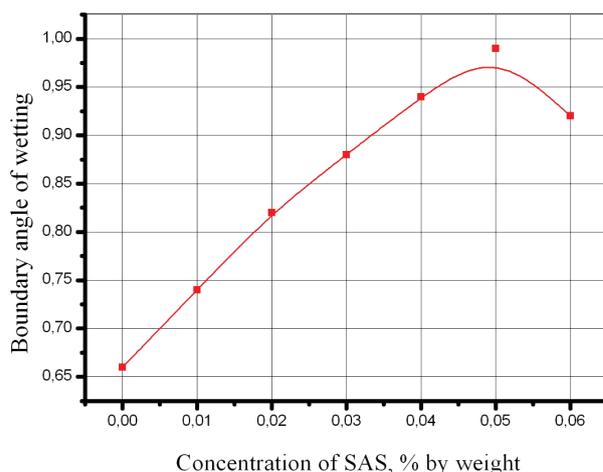


Fig. 3. Change in boundary cosine of angle of wetting in course of extracting chonsuride under SAS influence

Approximation dependences for all graphs were calculated in the MatCAD programming environment.

Experimental data on the dependence of coefficient of surface tension of extractant of chonsuride on the mass concentration of SAS are best described by polynomial function of the eighth order, the analytical expression of which takes the following form:

$$y = -470,0051 - 2,1874 \cdot 10^3 x - 3,4071 \cdot 10^3 x^2 + 2,8053 \cdot 10^3 x^3 - 1,3518 \cdot 10^3 x^4 + 393,7770 x^5 - 68,1534 x^6 + 6,4398 x^7 - 0,2554 x^8.$$

Experimental results of dependence of the resulting coefficient of cosine of the angle of wetting on the SAS mass concentration are best approximated by polynomial of the seventh order, the analytical expression of which takes the following form:

$$y = -0,0634 + 2,9982x - 3,8562x^2 - 2,4543x^3 - 0,8458x^4 - 0,1612x^5 - 0,0160x^6 + 6,4930 \cdot 10^{-4}x^7.$$

Propanol, butanol and the mixture of propanol with butanol in equal parts were added to the industrial extractant. Percentage mass content of alcohols, at which the industrial extractant has minimum coefficient of surface tension, was determined experimentally. 0,1; 0,2; 0,3; 0,4; 0,5; 0,6; 0,7; 0,8; 0,9 ml of alcohols with different molecular weight were added to 10 ml of the 5 % NaCl solution. Coefficient of surface tension was measured by the method of drop weighing (Fig. 4).

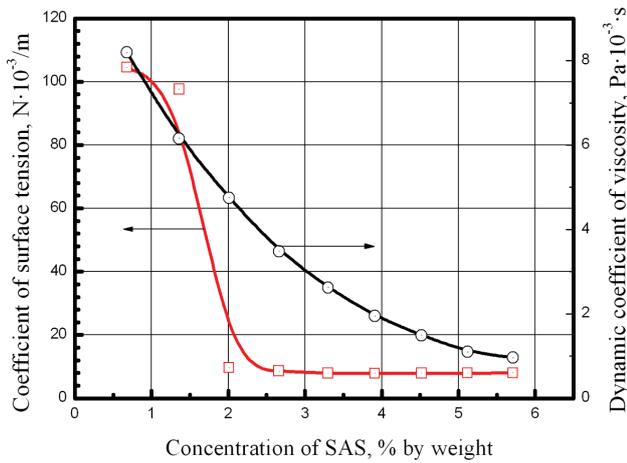


Fig. 4. Change in coefficient of surface tension and dynamic coefficient of viscosity of the extractant of heparin under the influence of propanol alcohol; 1 – coefficient of surface tension, 2 – dynamic coefficient of viscosity

Experimental findings of the resulting dependence of coefficient of surface tension of the industrial extractant of heparine on the mass concentration of SAS (propanol) are best approximated by polynomial of the eighth order, the analytical expression of which takes the form:

$$y = -69,4063 + 1,2242 \cdot 10^3 x - 3,1070 \cdot 10^3 x^2 + 3,5999 \cdot 10^3 x^3 - 2,2162 \cdot 10^3 x^4 + 767,3983x^5 - 149,8438x^6 + 15,3953x^7 - 0,6471x^8.$$

The minimum of coefficient of surface tension $\sigma = 5,75 \times 10^{-3} \text{ N/m}$ of the extractant of heparine was observed when adding 0,5 ml of propanol to 10 ml of the extractant (Fig. 4). Adding such amount of propanol also helps to decrease the magnitude of dynamic coefficient of viscosity (Fig. 4). Substantial decrease in the minimum of coefficient of surface tension $\sigma = 5,16 \cdot 10^{-3} \text{ N/m}$ (Fig. 5) is observed when using butanol in the mass amount of 0,5 ml per 10 ml of the extractant.

Dynamic coefficient of viscosity of the industrial extractant (5 % NaCl), as well as that of the proposed extractant (with the addition of 0,5 % by weight butanol alcohol to the industrial solution) were determined by the Arrhenius device. In the proposed extractant, the value of dynamic coefficient of viscosity of the solution decreased.

In this case, experimental results of the dependence of coefficient of surface tension on the mass concentration of SAS (butanol) are best approximated by polynomial of the eighth order, the analytical expression of which takes the form:

$$y = -69,4063 + 1,2242 \cdot 10^3 x - 3,1070 \cdot 10^3 x^2 + 3,5999 \cdot 10^3 x^3 - 2,2162 \cdot 10^3 x^4 + 767,3983x^5 - 149,8438x^6 + 15,3953x^7 - 0,6471x^8.$$

Experimental results of the dependence of coefficient of dynamic viscosity on the mass concentration of SAS (butanol) are approximated by polynomial of the second order, the analytical expression of which takes the form:

$$y = 11,9799 - 4,8455x + 0,4944x^2.$$

An industrial extractant of heparin is a weakly concentrated saline solution, so it was decided to add the mixture of propanol and butanol in equal ratio for an even larger decrease in coefficient of surface tension and dynamic coefficient of viscosity.

The minimum of coefficient of surface tension $\sigma = 6,67 \times 10^{-3} \text{ N/m}$ (Fig. 6) is observed when adding 0,6 ml of the mixture of alcohols (butanol with propanol) to 10 ml of the industrial extractant. Coefficient of dynamic viscosity also decreases.

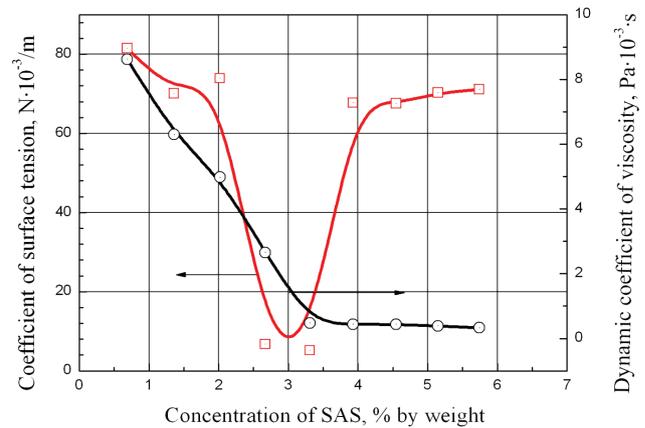


Fig. 5. Change in coefficient of surface tension and dynamic coefficient of viscosity of the extractant of heparin under the influence of butanol; 1 – coefficient of surface tension, 2 – dynamic coefficient of viscosity

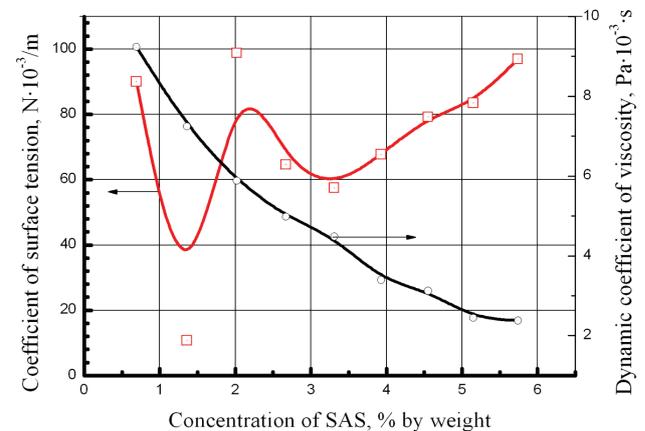


Fig. 6. Change in coefficient of surface tension and dynamic coefficient of viscosity of the extractant of heparin under the influence of SAS (mixture of alcohols of propanol and butanol in equal ratio); 1 – coefficient of surface tension, 2 – dynamic coefficient of viscosity

With adding butanol to the extractant of heparin, the cosine of angle of wetting also changes (Fig. 7). An analysis of Fig. 3–6 demonstrates that adding butanol to the industrial extractant of heparin exerts the best influence on the change in physical indices of the solution, required for the calculation of the mean thickness of the near-surface laminar layer while extracting heparin.

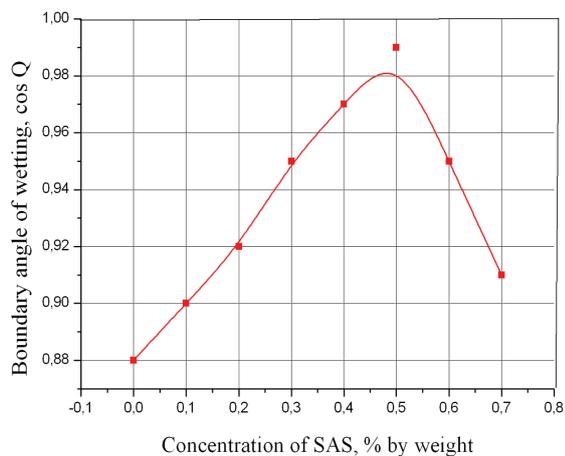


Fig. 7. Change in cosine of angle of wetting of the extractant of heparin under the influence of SAS (butanol)

Dependences of the resulting cosine of angle of wetting on the mass concentrations of SAS (butanol) are approximated by polynomial of the second order, the analytical expression of which takes the form:

$$y = 0,7972 + 0,0429x - 4,0832 \cdot 10^{-3}x^2.$$

To decrease coefficient of surface tension and coefficient of dynamic viscosity of the extractant of ronidaze, propanol and butanol were added to the solution. The rational mass amount of alcohols was determined experimentally by adding from 0,1 to 1 ml of propanol and butanol to 10 ml of the extractant. The industrial extractant of ronidase has in its composition 0,25 % of chloroform, which is a volatile substance. Therefore, for the accuracy of determining the coefficient of surface tension, we selected the method of Rehbindler [22].

A decrease in coefficient of surface tension and its minimum (Fig. 8) are observed when adding 0,8 ml of propanol. The optimal minimum coefficient of surface tension will be reached when adding 0,5–0,6 ml of butanol.

An analysis of the conducted studies demonstrates that in order to intensify the process of extraction of ronidase, we use butanol in the mass concentration of 0,5–0,7 ml per 100 ml of the solution as SAS in the industrial solution of the extractant. Coefficient of surface tension decreases gradually, depending on the increase in mass concentrations of alcohols. When coefficient of surface tension reaches its minimum, it almost does not change. This is explained by the fact that the extractant of ronidase has low salt concentration and its physical indices are close to those of water. Adding alcohols decreases coefficient of surface tension by three-four times, regardless of the concentration of alcohol.

For the industrial extractant of ronidase, the approximations dependences of the resulting coefficient of surface tension on the mass concentration of SAS in the extractant of ronidase are well approximated by polynomial of the third order:

$$y = 65,9823 - 16,6411x + 2,3996x^2 - 0,1137x^3.$$

An application of the proposed extractant of ronidase with butanol helps to decrease dynamic coefficient of viscosity (Fig. 9) and increase cosine of angle of wetting (Fig. 10), which is a good indicator for a decrease in the mean thickness of the near-surface laminar layer.

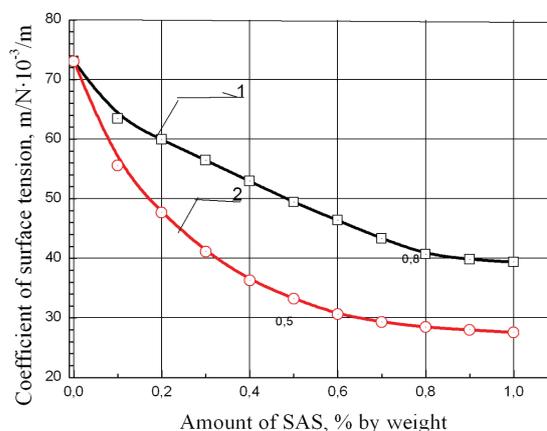


Fig. 8. Coefficient of surface tension of the extractant of ronidase under the influence of SAS: 1 – propanol; 2 – butanol

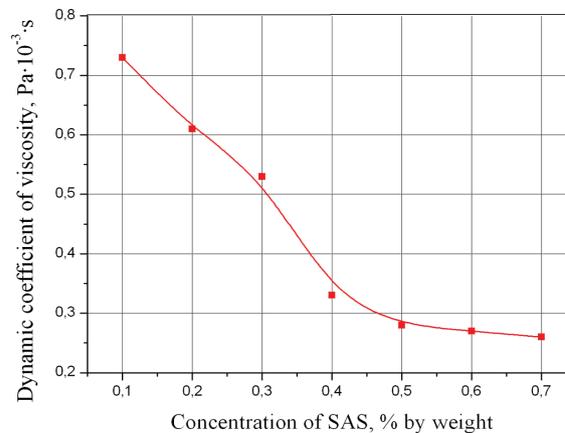


Fig. 9. Dynamic coefficient of viscosity of the extractant of ronidase under the influence of SAS

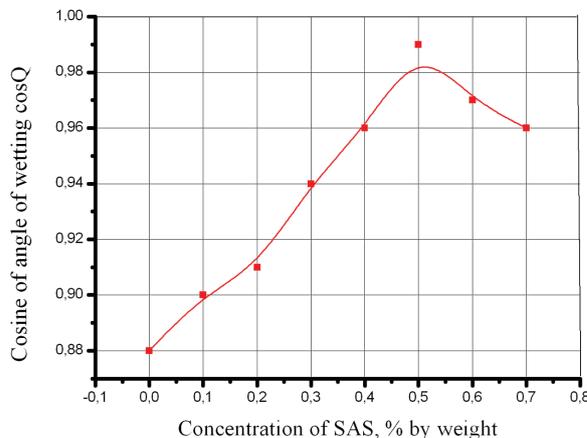


Fig. 10. Cosine of angle of wetting of the extractant of ronidase under the influence of SAS

Dependences of coefficient of dynamic viscosity of the extractant of ronidase on the mass concentrations of SAS

(butanol) are approximated by polynomial of the third order, the analytical expression of which takes the form:

$$y = 2,3086 - 0,5498x + 0,0553x^2 - 9,0198 \cdot 10^{-4}x^3.$$

Dependences of coefficient of cosine of angle of wetting of the extractant of ronidase on the mass concentration of SAS (butanol) are approximated by polynomial of the fourth order, the analytical expression of which takes the form:

$$y = 0,8998 + 0,0312x - 1,1136 \cdot 10^{-3}x^2 - 8,7076 \cdot 10^{-4}x^3 + 9,4496 \cdot 10^{-5}x^4.$$

Conducted studies proved that the addition of the established mass concentrations of butanol to the industrial extractants of chonsurid, heparin and ronidase contributes to changing physical indices of the solutions. Under the influence of SAS that were added to the extractants of organopreparations, density of the industrial extractants was also partially decreased (Table 1).

Table 1

Change in physical indices of the industrial extractants of chonsurid, heparin and ronidase under the influence of SAS ($p \geq 0,95$, $n=3$)

Characteristics	Extractants of chonsurid		Extractant of heparin		Extractants of ronidase	
	Industrial	with SAS	Industrial	with SAS	Industrial	with SAS
P_p , kg/m ³	1320	–	664	664	1368	–
P_e , kg/m ³	1181	1165	1039	1030	980	968
σ , N/m	0,0874	0,0561	0,0950	0,0516	0,07305	0,02843
M , Pa·s	0,00122	0,00042	0,00105	0,00025	0,00194	0,00078
$\cos\theta$	-0,66	0,99	0,88	0,98	0,88	0,98

An increase in the concentration of the target component during the application of the proposed solutions with the addition of the selected concentrations was proved by studies of kinetics of the extraction.

The studies were carried out repeatedly for each organopreparation with the same ratio of raw materials and the extractant. Diameter of crushing of the raw material was accepted as $1 \cdot 10^{-3}$ m. To study kinetics of the extraction, we used industrial extractant of chonsurid, heparin and ronidase, as well as the extractants with the mass concentration of selected SAS established experimentally (Fig. 11–13).

Concentration of the target component of chonsurid is increasing over time while using the proposed extractant with SAS (Fig. 11). During the extraction, the output of substances of the extract during the use of the industrial solution $\bar{c} = 1,96\%$ to the mass of raw material, and during extracting by the solution with SAS $\bar{c}' = 2,74\%$ for the same period of time. If we compare the mass of output of target components during the extraction with different extractants, we will obtain: $\frac{\bar{c}'}{\bar{c}} = \frac{2,74}{1,96} = 1,4$ times increase in the mass of output of the extract during the extraction of chonsurid at the 25% KCl solution in the 1% K₂CO₃ with the addition of 0,05–0,06% by weight of butanol alcohol.

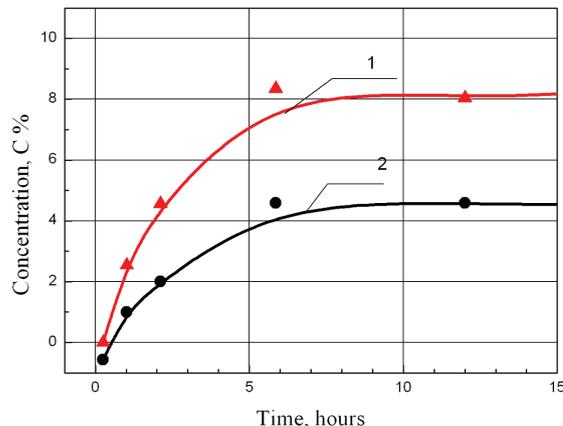


Fig. 11. Output of mass of the substance of chonsurid depending on the use of extractant: 1 – extractant with the addition of SAS; 2 – industrial extractant

Fig. 12 shows an increase in concentration of the substance of heparin over time during the use of the solution with SAS, proposed during the study, as an extractant. During the 1,5-hour extraction, the output of the target component during the use of the industrial solution is $\bar{c} = 0,5\%$ to the mass of raw material, and during extracting by the solution with SAS, the mass of the target component is $\bar{c}' = 0,85\%$. Having compared the mass of the output of target components of heparin during extraction with different extractants, we obtained: $\frac{\bar{c}'}{\bar{c}} = \frac{0,85}{0,5} = 1,7$ times increase in the output of substances. Using the 5% solution of NaCl with 0,5–0,6% by weight of butanol alcohol for the extraction of heparin contributes to the intensification of the process as a whole.

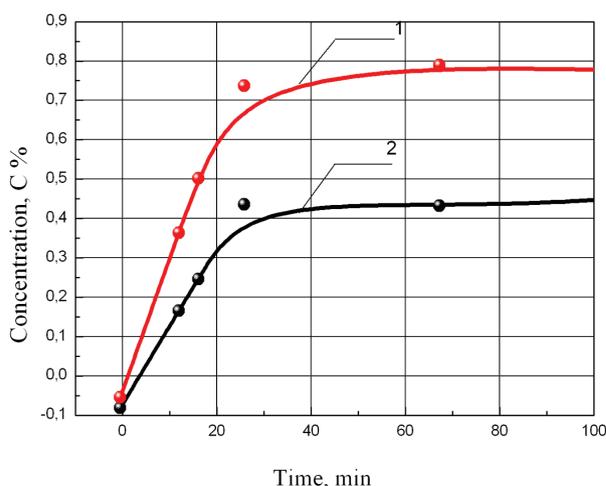


Fig. 12. Output of mass of the substance of heparin depending on the use of extractant: 1 – extractant with the addition of SAS; 2 – industrial extractant of heparin

Positive changes during study of kinetics of the extraction of ronidase with the use of extractant with the addition of 0,45–0,65% by weight of butanol is shown in Fig. 13. Mass of the substance of ronidase during 1,5-hour extraction with the use of industrial solution is $\bar{c} = 5,2\%$, and mass of the output of substances during extracting with the solution of SAS is $\bar{c}' = 9,98\%$ to the mass of raw mate-

rial. Having compared the masses of extracts when using different extractants, we obtained: $\frac{c'}{c} = \frac{9,98}{5,2} = 1,9$ times of increase in mass concentration of the extract using the 0,9 % solution of sodium chloride with 0,25 % of chloroform with the addition of SAS 0,45–0,65 % butanol.

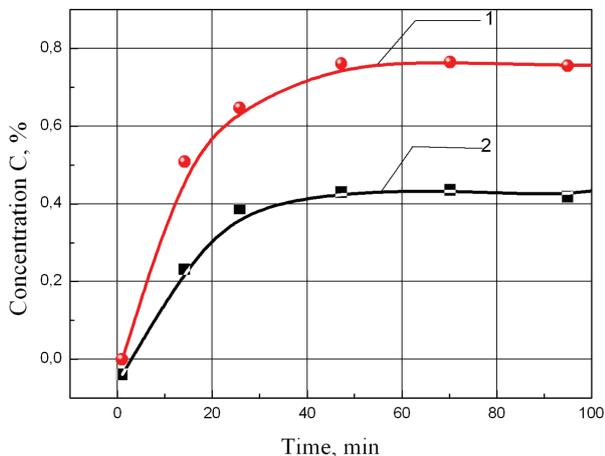


Fig. 13. Output of mass of the substance of ronidase depending on the use of extractant: 1 – extractant with the addition of SAS, 2 – industrial extractant

A decrease in the values of physical characteristics of extractant influences the change in the surface number and describes attenuation of the action of surface forces. Lower values of the surface number indicate a decrease in the diffusion resistance of the system “solid body-liquid” in the course of production of chonsurid, heparin and ronidase, which is a consequence of the decrease in the mean thickness of the near-surface laminar layer.

Surface number is calculated by formula:

$$P_o = 2\pi\sigma\cos\theta/V_x^2\delta\rho,$$

where σ is the surface tension coefficient, N/m; $\cos\theta$ is the boundary angle of wetting; V_x is the speed in the near-wall layers, m/s; ρ is the density of medium, kg/m³; δ is the mean thickness of the near-surface laminar layer, m·10⁻³.

A change in the surface number is observed with a change in coefficient of surface tension of the extractants (Fig. 14–16).

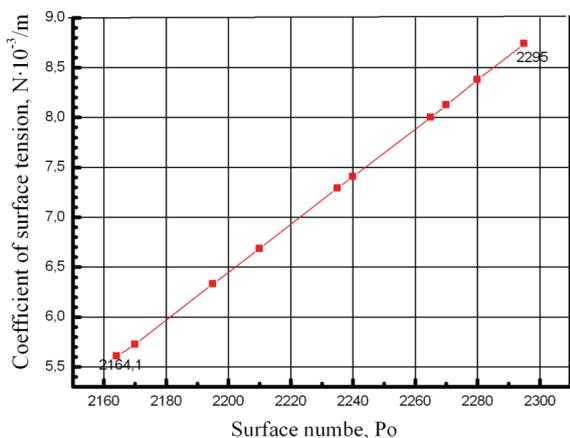


Fig. 14. Dependence of surface number on coefficient of surface tension of the solution in the production of chonsurid

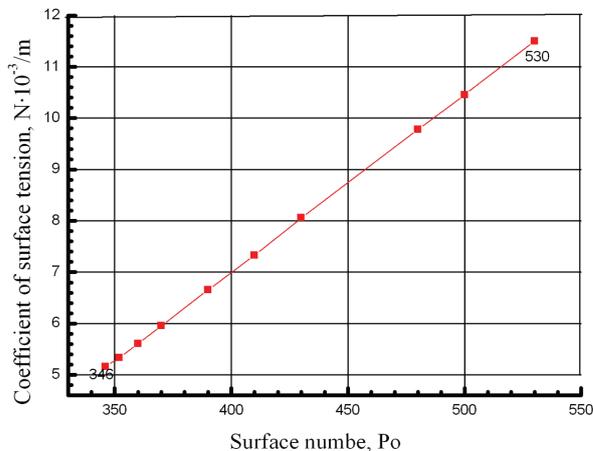


Fig. 15. Dependence of surface number on coefficient of surface tension of the solution in the production of heparin

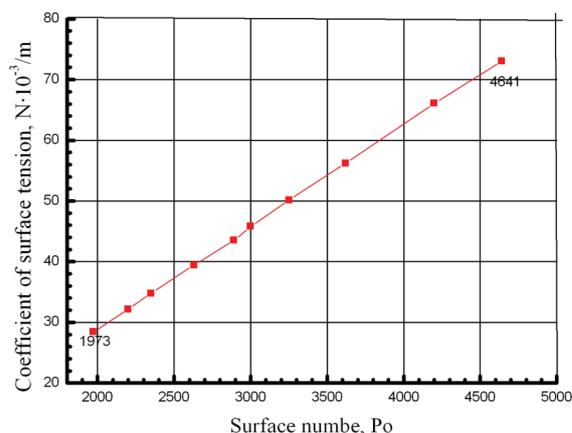


Fig. 16. Dependence of surface number on coefficient of surface tension of the solution in the production of ronidase

Performed calculations of the value of surface number, as well as the value of the Archimedean, Euler and Reynolds numbers (Table 2) in a near-surface laminar layer during the extraction of organopreparations with the use of various extractants prove positive changes when applying the extractants with SAS.

Table 2

Basic numbers in a near-surface laminar layer

Similarity number	Industrial extractant			Proposed extractant with SAS		
	chonsurid	heparin	ronidase	chonsurid	heparin	ronidase
Archimedean number	1028	3463	990	10028	59110	6236
Reynolds number	18,6	34,8	17,5	91,5	265	65,1
Euler number	170	99,2	69,9	37,5	11,3	12
Surface number	2295	530	4641	2164	346	197

Such numbers are responsible for the force factors of influence on the elementary volume of solution in a laminar layer at the output of extract from crushed parts of raw materials. When using the proposed solutions, the Archime-

dean and Reynolds numbers increase, which indicates the improvement of hydrodynamic situation.

6. Discussion of results of the influence of SAS on the hydrodynamic indices of extraction

Studies of kinetics of the extraction prove an increase in the concentration of the target component when using the proposed solutions with the addition of appropriate concentrations of SAS.

Having compared the Euler number in cases involving the use of industrial extractant and the extractant proposed as a result of the studies, we saw a decrease in this index when applying the solution with SAS. A similar parallel can be drawn when comparing surface numbers when using the industrial and the proposed extractants with SAS.

A change in the surface number, which depends on the coefficient of surface tension of the extractant of chonsurid that changes under the influence of different mass concentrations of SAS, is displayed in Fig. 14. With the addition of 0,05–0,06 % by weight of butanol to the industrial solution, the surface number will be minimal. When using the extractant with SAS, the surface criterion decreases, and this means that the action of friction forces and surface forces also decreases. Due to their decrease, diffusion resistance around a crushed particle of cartilage decreases at the extraction of chonsurid. At the mean thickness of the near-surface L-layer of $7,2 \cdot 10^{-3}$ mm, diffusion resistance is 98 %, whereas at the mean thickness of L-layer $1,1 \cdot 10^{-3}$ mm, diffusion resistance is 15 %.

An application of experimentally established mass concentrations of butanol in the extractant of chonsurid changes physical indices of the industrial solution, which affect attenuation of near-surface forces in the laminar layer and contribute to the decrease in diffusion resistance of the system. A consequence of these changes is an increase in the output of chonsurid substances.

A decrease in the value of surface number occurs when using different concentrations of butanol in the extractant of heparin (Fig. 15). The change in hydrodynamic indices in the system under the influence of SAS (Table 2) helps to reduce diffusion resistance, which ensures an increase in the output of the extract from crushed particles of the lungs

(raw material). At the mean thickness of the near-surface L-layer $9,7 \cdot 10^{-3}$ mm, diffusion resistance is 98 %, and at the mean thickness of L-layer $0,98 \cdot 10^{-3}$ mm, diffusion resistance is 9 % [9, 18].

The optimal value of SAS for an extractant in the production of ronidase with the concentration of SAS at 0,5 % by weight of butanol, surface number decreases significantly (Fig. 16). Intensification of the extraction of ronidase under the influence of SAS takes place due to the attenuation of force field in the surface laminar layer and, consequently, helps to reduce diffusion resistance. At the mean thickness of the near-surface L-layer $4,8 \cdot 10^{-3}$ mm, diffusion resistance is 98 %, and at the mean thickness of L-layer $0,807 \cdot 10^{-3}$ mm, diffusion resistance index is 16,5 % [13, 19, 25].

7. Conclusions

It is proven that for the assessment of hydrodynamic situation on the border of the solid body-liquid contact, it is advisable to use surface number as an index of the decrease in diffusion resistance.

1. As a result of the studies, we proved effectiveness of the application of SAS in the extractants of chonsurid in the amount of 0,05–0,06 % by weight of butanol, in the extractants of heparin – 0,05 % by weight of butanol, in the extractants of ronidase – 0,5–0,6 % by weight of butanol.

2. It was experimentally determined that adding rational concentrations of SAS to the extractants of the examined group of organopreparations contributes to the decrease in mean value of coefficients of surface tension of the extractants: for chonsurid – by 6 times, for heparin – by 9 times, for ronidase – by 5 times, and their magnitudes are: for chonsurid – 3 mm, for heparin – 1 mm, for ronidase – 1 mm, respectively. The values of dynamic viscosity coefficient, cosines of angles of wetting and density of the proposed solutions also decrease.

3. Theoretical calculations confirmed that a decrease in the mean thickness of a near-surface laminar layer is observed when using the proposed extractants with SAS.

4. It was established that adding rational concentrations of SAS influences intensification of the extraction. The output of chonsurid increases by 1,4 times, of heparin – by 1,7 times, of ronidase – by 1,9 times.

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