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КИНЕТИКА ИЗМЕЛЬЧЕНИЯ РАСТИТЕЛЬНОГО СЫРЬЯ ПРИ ЭЛЕКТРОРАЗРЯДНОМ ЭКСТРАГИРОВАНИИ

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Изучено влияние степени измельчения частиц растительного сырья при электроразрядном экстрагировании на качество полученных экстрактов. Каждый разряд при электроразрядном экстрагировании способствует измельчению частичек сырья, что подтверждается гранулометрическим анализом. Крупность частиц сырья должна быть под контролем, так как при чрезмерном измельчении экстракты получаются мутные, трудно осветляемые и плохо фильтруемые. Предложена конструкция экстракционной камеры, в которой заземленный электрод выполнен в виде перфорированной пластины, называемой ложным дном, с оптимальными размером отверстий и их плотностью, что позволяет устранить переизмельчение частичек исходного сырья, которое приводит к получению мутных и трудно фильтруемых вытяжек. Поскольку экстрагирование сырья осуществляется при определенном соотношении фаз твердое-жидкость, то объем камеры от сита до дна существенного влияния на кинетику самого процесса экстрагирования не оказывает, поскольку предназначен для сбора мельчайших частиц обработанного сырья, масса которых не превышает 15-16% от загружаемой массы сырья. Устройство экстракционной камеры, за счет высокой турбулентности и интенсивного перемешивания суспензии под действием кавитации и ударных волн, инициируемых разрядом в жидкости, позволяет удалять из рабочей зоны камеры мелкие частички сырья размером менее 1 мм. Результаты исследования показывают, что экстракция целевых компонентов из различного сырья при помощи камеры с ложным дном позволяет существенно сократить содержание в экстракте мельчайших частичек сырья. Облегчается фильтрование экстракта, сокращается время фильтрования, значительно снижается вероятность помутнения раствора из-за взвеси, что повышает качество экстракта. Экспериментальные исследования разработанной электроразрядной камеры с ложным дном, проведенные с различными видами растительного сырья, подтверждают эффективность экстрагирования в камере предложенной конструкции.

Ключевые слова: электрический разряд, экстрагирование, электроразрядная камера, измельчение, гранулометрический анализ, перфорированный электрод, ложное дно

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KINETICS OF GRINDING OF VEGETABLE RAW MATERIALS DURING ELECTRIC DISCHARGE EXTRACTION

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The influence of the degree of grinding of the particles of growing raw materials during electric discharge extraction on the quality of the obtained extracts was studied. Each discharge during electro-discharge extraction contributes to the grinding of a part of the raw material, which is confirmed by granulometric analysis. The particle size of the raw material should be controlled, since excessive grinding of the extracts results in cloudy, difficult to clarify and poorly filtered. The design of the extraction chamber is proposed, in which the grounded electrode is made in the form of a perforated plate, called a false bottom, with the optimal size of the holes and their density, which eliminates the over-grinding of the raw material particles, which leads to the production of turbid and difficult-to-filter extracts. Since the extraction of raw materials is carried out at a certain ratio of solid-liquid phases, the volume of the chamber from the sieve to the bottom does not significantly affect the kinetics of the extraction process itself, since it is intended for collecting the smallest particles of processed raw materials, the mass of which does not exceed 15-16% of the loaded mass of raw materials. The device of the extraction chamber, due to the high turbulence and intensive mixing of the suspension under the action of cavitation and shock waves initiated by the discharge in the liquid, allows you to remove small particles of raw materials less than 1 mm in size from the working area of the chamber. The results of the study show that the extraction of target components from various raw materials using a chamber with a false bottom can significantly reduce the content of the smallest particles of raw materials in the extract. It facilitates the filtration of the extract, reduces the filtration time, significantly reduces the likelihood of turbidity of the solution due to suspension, which improves the quality of the extract. Experimental studies of the developed electric discharge chamber with a false bottom, conducted with various types of plant raw materials, confirm the effectiveness of extraction in the chamber of the proposed design.

Key words: electric discharge, extraction, electric discharge chamber, grinding, particle size analysis, perforated electrode, false bottom

INTRODUCTION

It is known that the effect of electric discharges allows to significantly intensify the process of extraction of target components from various starting materials, including from plant raw materials [1-7]. It is also known that the quality of the obtained extracts is significantly affected by the degree of grinding of the plant material particles, including during electric discharge extraction [5-8].

Increasing the energy efficiency of the process of extracting various components from vegetable, fibrous and other types of raw materials under the influence of ultrasonic and pulsed electric fields is an urgent task. Of scientific novelty and practical interest is the improvement of the design of extraction devices and the operating parameters of the intensified extraction processes with high quality of the target products, the established relationship between the action of electric discharges and the granulometric composition of the growing raw materials.

The aim of the work is to study the effect of the degree of grinding of plant raw materials during electric discharge extraction on the quality of extracts.

The tasks and methods of the study were determined on the basis of the analysis of the mechanism of the effect of electric discharges in the liquid phase during extraction. The object of the study was the process of electric discharge extraction from vegetable raw materials.

An electric discharge in a liquid at the initial stage of development is accompanied by the nucleation and collapse of cavitation bubbles. The compression-rarefaction waves formed in this process lead to the grinding of the particles of the processed material. In the final stage of the discharge, when the channel bridges the interelectrode gap, a sudden increase in the channel temperature occurs and a vapor-gas cavity is formed [3, 5-9].

Pulsations of the vapor-gas cavity create a hydrodynamic environment in the volume, which provides a sudden change in pressure and high turbulence of the suspension movement in the working chamber. This serves as a source of grinding of the solid phase and activates internal diffusion processes when extracting plant raw materials from the cell and intercellular space. Probably, due to high-frequency oscillations and high turbulence of the liquid flow in the mouths of the capillaries, the mass transfer rate will increase [6].

To increase the rate of extraction of the target components from the organic raw material, it is pre-crushed in order to increase the initial surface of the particles interacting with the extracting liquid.

This is a fairly energy-intensive process, since the raw materials are elastic-plastic materials, stored in conditions with a certain humidity and its grinding is carried out in a wet state. When dehydrated, the raw material becomes brittle and can easily be turned into powder, which will further complicate the extraction process. In electric discharge extraction, each discharge contributes to the grinding of raw material particles, which is confirmed by granulometric analysis. The particle size of the raw material should be controlled, since excessive grinding results in cloudy extracts, difficult to clarify and poorly filtered [9-16].

RESULTS AND THEIR DISCUSSION

Fig. 1 shows the device of the extraction chamber for electro-discharge extraction of target components from the initial plant raw materials, developed at the Pyatigorsk Medical and Pharmaceutical Institute.

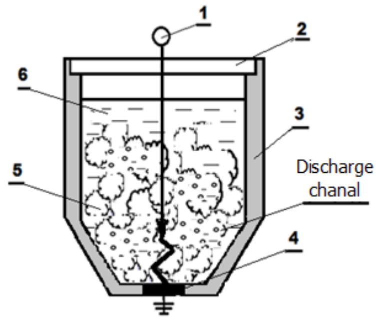

Fig. 1. Extraction chamber for electric discharge extraction 1 – high-voltage electrode; 2-extractor cover; 3-polyethylene body of the extraction chamber; 4-grounded electrode; 5-raw materials in the extraction process; 6-extractant

Рис. 1. Экстракционная камера для электроразрядного экстрагирования 1 – высоковольтный электрод; 2 – крышка экстрактора; 3 – полиэтиленовый корпус экстракционной камеры; 4 – заземленный электрод; 5 – сырье в процессе экстрагирования; 6 – экстрагент

Numerous studies have shown that the disadvantages of this device of the electric discharge chamber are the over-grinding of raw material particles as they are extracted, since the smallest particles are not removed from the core of the chamber, as a result of which the extracts are cloudy and difficult to filter [5-10].

The authors developed the design of the extraction chamber, which allows to eliminate this drawback. For this purpose, the grounded electrode is made in the form of a perforated plate, hereinafter referred to as a false bottom with a hole size of 1 mm and a hole density of 16 pieces/cm^2. The electrode is installed at a distance of 3 cm from the bottom of the extraction chamber.

The false bottom extraction chamber is shown in Fig. 2.

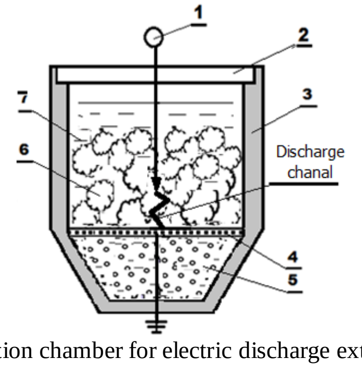

Fig. 2. Extraction chamber for electric discharge extraction with a false bottom 1 – high-voltage electrode; 2 – extraction chamber cover; 3 – extraction chamber body; 4 – perforated ground electrode - false bottom; 5 – raw material particles less than 1 mm in size; 6 – feedstock; 7 – extractant

Рис. 2. Экстракционная камера для электроразрядного экстрагирования с ложным дном 1 – высоковольтный электрод; 2 – крышка экстракционной камеры; 3 – корпус экстракционной камеры; 4 – перфорированный заземленный электрод - ложное дно; 5 – частички сырья размером менее 1 мм; 6 – исходное сырье; 7 – экстрагент

Since the extraction of raw materials is carried out with a solid-liquid phase ratio of 1: 10-1:15, the volume of the chamber, from the sieve to the bottom, does not significantly affect the kinetics of the extraction process itself, since it is designed to collect the smallest particles of the processed raw materials, the mass of which does not exceed 15-16% of the total loaded mass of raw materials.

Such a device of the extraction chamber, due to the high turbulence and intensive mixing of the suspension under the action of cavitation and shock waves initiated by the discharge in the liquid, allows you to remove raw material particles of less than 1 mm in size from the working area of the chamber. This, in the end, facilitates the subsequent filtration of the extract and reduces the time for its implementation, significantly reduces the possibility of turbidity of the solution due to suspension, which improves the quality of the extract.

Tables 1-4 show the data that substantiate the proposed design of the extraction chamber with a false bottom. The extraction was carried out from the fruits of Sophora japonica in the chamber shown in Fig. 1 and in the chamber shown in Fig. 2, with the same working parameters. The number of discharges, the mass of raw materials, and the phase ratio were the same.

Before extraction, the size of the feedstock was analyzed. Then the raw material was loaded into the extraction chamber at a certain ratio with the extractant and extracted under the action of electric discharges. After the extraction process was completed, the raw materials were dried and subjected to granulometric analysis, the results of which are presented in Table 1.

The results of the granulometric analysis show that the number of particles with a size of less than 1 mm increased from 2.75% (in the initial state) to 15.44% after a series of discharges, i.e. by 5.6 times. And since the extraction processes are carried out three times with a change of extractant in each batch, the number of tiny particles in the extraction chamber will increase many times, which ultimately leads to additional costs for filtering and clarifying the extract.

From the same batch of plant raw materials, a sample was taken and placed in an extraction chamber for electric discharge extraction with a false bottom. The results of the study are shown in Table 2.

As follows from the table. 2 the total number of particles of 0.5 and 1.0 mm in size after extraction in the chamber with a false bottom decreased by more than 7 times.

In the next series of experiments for the extraction were taken roots of scorzonera Spanish. The fineness of the scorzoner root crops after electric discharge extraction in the extraction chamber Fig. 1, is shown in Table 3.

Table 1

Change in the content of small particles of japanese sophora in the raw material after extraction in the extraction chamber for electric discharge extraction

Таблица 1. **Изменение содержания мелких частиц софоры японской в сырье после экстракции в экстракционной камере для электроразрядного экстрагирования**

Diameter of the screw hole, d, mm	Particle content in the raw material before extraction, Δd_0, %	Particle content in the raw material after extraction, Δ d, %
0.50	1.24	6.29
1.00	1.51	9.16
2.00	17.51	27.83
3.50	65.22	49.34
3.75	14.52	7.38

Table 2

Change in the content of small particles of japanese sophora in the raw material after extraction in the extraction chamber for electric discharge extraction with a false bottom

Таблица 2. **Изменение содержания мелких частиц софоры японской в сырье после экстракции в экстракционной камере для электроразрядного экстрагирования с ложным дном**

Diameter of the screw hole d, mm	Particle content in the raw material before extraction Δd_0, %	Particle content in the raw material after extraction Δd, %
0.50	1.24	0.22
1.00	1.51	0.17
2.00	17.51	24.79
3.50	65.22	67.31
3.75	14.52	7.52

Table 3

Change in the content of small particles of spanish scorzoner root crops in the raw material after extraction in the extraction chamber for electro-discharge extraction (a sieve was added with a cell size of 1.25 mm)

Таблица 3. **Изменение содержания мелких частиц корнеплодов скорцонера испанского в сырье после экстракции в экстракционной камере для электроразрядного экстрагирования (добавлено сито с размером ячейки 1,25 мм)**

Diameter of the screw hole d, mm	Particle content in the raw material before extraction Δd_0, %	Particle content in the raw material after Extraction Δd, %
0.50	2.50	4.50
1.00	4.50	19.17
1.25	10.50	18.83
2.00	10.83	20.83
3.50	64.17	32.50
3.75	7.50	4.17

The results show that the total content of particles smaller than 1 mm increased from 7% to 23.67%, i.e. increased by 3.38 times.

The change in the size of the scorzoner root crops after elec-tror-row extraction in the extraction chamber with a "false bottom" is shown in Table 4.

Table 4

Change in the content of small particles of the spanish scorzoner root crops in the raw material after extraction in the extraction chamber for electro-discharge extraction with a false bottom

Таблица 4. **Изменение содержания мелких частиц корнеплодов скорцонера испанского в сырье после экстракции в экстракционной камере для электроразрядного экстрагирования с ложным дном**

Diameter of the screw hole d, mm	Particle content in the raw material before extraction Δd_0, %	Particle content in the raw material after extraction Δd, %
0.50	2.50	0.51
1.00	4.50	3.17
1.25	10.50	23.92
2.00	10.83	26.34
3.50	64,17	41.89
3.75	7.50	4.17

The data in Table 4 show that the extraction of the target components from the root crops of the scorzoner using a chamber with a false bottom reduces the content of the smallest particles of raw materials in the extract by more than 5.6 times.

The intensification and increase of the energy resource efficiency of the extraction process of various components from plant, fiber and other raw materials under the influence of physical fields, including pulsed electric fields, as can be seen from publications and review materials presented in journals and proceedings of international conferences, is modern and promising [16-18]. Research and development of mathematical models of the extraction process and methods of its calculation are carried out. An important direction is to improve the designs and operating parameters that allow us to improve the quality of the target products [17-20].

CONCLUSIONS

The studied electric discharge chamber with a false bottom allows to remove from the working area, due to high turbulence and intensive mixing of the suspension under the action of cavitation and shock waves initiated by the discharge, raw material particles with a size of less than 1 mm, which consequently eliminates turbidity of the extract due to overgrinding, lightens and reduces the time for filtration, resulting in an increase in the quality of the extract.

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