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Shaxnoza Abduvaxitovna Sultanova
Tashkent State Technical University Address: 2 Universitetskaya st., 100095, Tashkent city, Republic of Uzbekistan E-mail: 1sh.sultanova@yahoo.com, Phone: +99893 506-22-00;, sh.sultanova@yahoo.com

Jasur Esirgapovich Safarov
Tashkent State Technical University Address: 2 Universitetskaya st., 100095, Tashkent city, Republic of Uzbekistan E-mail: jasursafarov@yahoo.com, Phone: +99893 569-02-88;, jasursafarov@yahoo.com

Azamat Usenov
Tashkent State Technical University Address: 2 Universitetskaya st., 100095, Tashkent city, Republic of Uzbekistan, E-mail: azamat_usenov_92@mail.ru, Phone: +99894 205-35-75;, azamatusenov1111@gmail.com

Doston Ishmuhammat ogli Samandarov
Tashkent State Technical University Address: 2 Universitetskaya st., 100095, Tashkent city, Republic of Uzbekistan, E-mail: Ishmuxammedovich@mail.ru, Phone: +99894 205-35-75.

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APPLICATION OF THE ULTRASONIC GENERATOR IN THE EXTRACTOR AND DETERMINATION OF ITS ENERGY CONSUMPTION

Sultanova Shaxnoza Abduvaxitovna[1], Safarov Jasur Esirgapovich[2], Usenov Azamat Bakir ogli[3], Samandarov Doston Ishmuhammat ogli[4]

[1,2,3,4]Tashkent State Technical University
Address: 2 Universitetskaya st., 100095, Tashkent city, Republic of Uzbekistan
E-mail: [1]sh.sultanova@yahoo.com, Phone: +99893 506-22-00; [2]jasursafarov@yahoo.com, Phone: +99893 569-02-88; [3]azamat_usenov_92@mail.ru, Phone: +99894 205-35-75; [4]Ishmuxammedovich@mail.ru Phone: +99894 205-35-75.

Abstract: *An ultrasonic generator was used in the Soxhlet extractor. To evaluate the process, the solvent flow was examined. The influence of the flow time in the Soxhlet on the process was analyzed. The formula for the residence time of streaming particles in the apparatus is given. A standardized volume curve V was formed. The time required for the solvent to remain in the apparatus is important during the extraction process. The description of the structure of flows of mass metabolic processes also means that it allows you to determine the movement and distribution of substances in these flows. Therefore, we wrote a hydrodynamic model of flows in the Soxhlet in the form of equations that represent the change in time in the apparatus. Ways to accelerate the extraction process are considered. The advantages of each method have been explored. Ultrasonic acceleration was selected from the investigated method. The parameters of the generator for generating ultrasound are considered. A compatible generator was selected. Selected "High Power Ultrosonic Generator" 40 kHz, 1.2 kW because it uses less power and does not affect the balance of the device. If a generator with high parameters is selected, the effect on the balance of the device is determined. For large extractors, a high-performance ultrasonic generator is recommended. The schematic diagram of the selected generator is taken from the reference book. We have performed a complete extraction process to estimate the energy consumption of the process. It turned out that the process, carried out with the help of ultrasound, is fast and energy efficient. The experiments took over an hour to evaluate the process. While 10 ml of the substance was extracted from the extracted basil leaf for one hour, 15 ml of the substance was separated from the addition process by sonication for one hour. In each experiment, the mode was chosen the same. Graphs were drawn to compare the results.*

Keywords*: extractor, soxhlet, ultrasonic generator, solvent, basil leaf, standardized curve, energy consumption.*

Аннотация*: Мақолада экстрактор сокслетида ултратовушли генератордан фойдаланиш жараёни тасвирланган. Жараённи баҳолаш учун эритувчи оқими текширилди. Сокслетдаги оқим вақтининг жараёнга таъсири таҳлил қилинди. Оқим зарраларининг аппаратда бўлиш вақтининг формуласи ва V ҳажмининг эгри чизиғи берилган. Экстракция жараёнида эритувчининг аппаратда қолиши учун зарур бўлган вақт муҳим аҳамиятга эга. Оммавий метаболик жараёнлар оқимлари тузилишини тавсифи, шунингдек, бу оқимларда моддаларнинг ҳаракатланиши ва тарқалишини аниқлашга имкон беришини англатади. Шунинг учун биз Сокслетда оқимларнинг гидродинамик моделини аппаратда вақт ўзгаришини ифодаловчи тенгламалар шаклида ёздик. Экстраксия жараёнини тезлаштириш усуллари кўриб чиқилган. Ҳар бир усулнинг афзалликлари ўрганилди. Ултрасоник тезлаштириш ўрганилаётган усулдан танланди. Ултратовуш ишлаб чиқариш учун генераторнинг параметрлари кўриб чиқилди. 40 кГц, 1,2 кВт частотали мос келадиган "High Power Ultrosonic Generator" генератори танланди, чунки у кам энергия сарфлайди ва қурилманинг мувозанатига таъсир қилмайди. Юқори параметрларга эга генераторни танлашда қурилманинг мувозанатига таъсири аниқланди. Катта экстракторлар учун юқори самарали ултратовушли генератор тавсия этилади. Жараённинг энергия сарфини баҳолаш учун биз тўлиқ экстраксия жараёнини амалга оширдик. Маълум бўлишича, ултратовуш ёрдамида амалга ошириладиган жараён тез ва энергияни тежовчи ҳисобланади. Жараённи баҳолаш учун тажрибалар бир соатдан кўпроқ вақтни олди. Экстракция қилинган райҳан баргидан бир соат давомида 10 мл моддалар чиқарилса, 15 соатлик модда қўшилиш жараёнидан бир соат давомида ултратовуш билан ажратилган. Ҳар бир тажриба битта режимда амалга оширилди. Натижаларни таққослаш учун графикалар тузилди.*

Таянч сўзлар: *экстрактор, сокслет, ултратовуш генератори, эритувчи, райҳон барги, стандарт эгри чизиқ, энергия сарфи.*

Аннотация: *В работе описана работа ультразвукового генератора, использованного в сокслете экстрактора. Исследован поток растворителя, проанализировано влияние времени прохождения потока в сокслете на процесс. Приведена формула времени пребывания частиц потока в аппарате и кривая стандартизированного объема V формировки. Время, необходимое для нахождения растворителя в аппарате, важно для экстракции. Описание структуры потоков массообменных процессов позволяет определять перемещение и распределение веществ в потоках. Получены гидродинамическая модель потоков в сокслете в виде уравнений, которые представляют собой изменение исследуемого параметра во времени в аппарате. Проанализированы способы ускорения процесса экстракции. Показаны преимущества и недостатки каждого метода было выбрано ультразвуковое ускорение. Рассмотрены параметры генератора для генерации ультразвука. Подобран совместимый генератор "High Power Ultrosonic Generator" с частотой 40 кГц, 1,2 кВт, потребляющий меньше энергии и не влияющий на баланс устройства. При выборе генератора с высокими параметрами, было выявлено влияние на материальный и тепловой балансы устройства. Для крупных экстракторов рекомендуется использование высокопроизводительного ультразвукового генератора. Изучен полный процесс экстракции, чтобы оценить энергопотребление процесса. Установлено, что процесс, выполняемый с помощью ультразвука, проходит быстрее и энергоэффективное. Эксперименты проводились более часа, 10 мл вещества экстрагировали из листа базилика в течение одного часа, 15 мл вещества были отделены процессом добавлением обработка ультразвуком в течение одного часа. Каждый эксперимент проводился в одном режиме.*

Ключевые слова: *экстрактор, сокслет, ультразвуковой генератор, растворитель, лист базилика, стандартизованная кривая, потребление энергии.*

Introduction

The use of energy efficient equipment is a modern requirement. Because energy conservation is an important indicator of economic development. Many reforms are underway in the field of food and chemical technologies. The widespread use of electronics and automation in industry leads to energy savings.

There are two ways to create energy-efficient equipment: the first is to create new equipment using modern parts, and the second is to add an additional device to the existing one to speed up the process. With this in mind, we interpreted the extraction process and compared the results [1–9].

1. Flow of Soxhlet Extractor Solvent

Extraction processes are one of the main ones in the food industry. It is widely used to extract essential substances from plants or agricultural products. For example, the extraction process, which is used in the production of food colors, flavorings, fruit juices, confectionery, and other industries, is more complex [9–16].

The behavior of streams in extractors is so complex that it is often impossible at present to construct a rigorous mathematical description of them. At the same time, it is known that flow-through systems have a significant effect on the efficiency of chemical-technological processes, which must be taken into account when modeling processes. In this case, mathematical models of the structure of flows are taken as the basis for the mathematical description of the chemical-technological process under construction. Therefore, the models of the structure of flows in the apparatus developed so far are much simpler and semi-empirical in nature. However, they make it possible to create models (models of objects) that accurately reflect real physical processes [10–15].

When carrying out chemical technological processes, it is often important to know the degree of completeness of their completion, which, in turn, depends on the temporal distribution of flow particles in the apparatus, since some parts of the flow can remain in the apparatus, while others - and vice versa, which is directly related to the contact time. and diffusion [15–18].

Analytically, we performed a mathematical calculation of the movement of the flow elements in the Soxhlet extractor. To do this, we will choose a Soxhlet extractor and study its principle of operation and structure.

The main working part of the extractor is the Soxhlet extractor. This is because the solvent dissolves the extracted substance in the Soxhlet. The solvent circulates in the apparatus until the end of the process. The vapor changes from a liquid state to a Soxhlet state. The solvent together with it removes the solutes. Thus, the solvent is re-circulated to separate substances [18]. The structure and flow direction of the Soxhlet extractor are shown in Fig. 1.

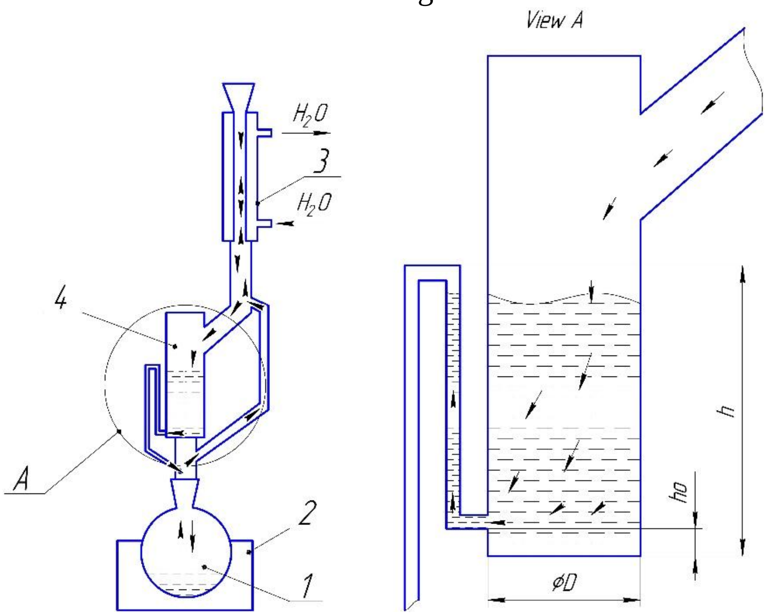

Fig. 1. ***General schematic view of the Soxhlet extractor.***
1 – solvent; 2 – heater; 3 – cooling device; 4 – soxhlet.

To calculate how long the solvent will remain in the Soxhlet, we define the variables as the flow rate *V*, the time in the Soxhlet, and the volumetric velocity *v*.

The amount of solvent in the Soxhlet varies from *t* to *t* + *dt*:

$$dg = vV(t)dt \tag{1}$$

The ratio *dg* to total solvent *g* is the percentage of solvent liberated from the device at time *t* + *dt*:

$$dp = \frac{dg}{g} = \frac{vV(t)dt}{g} \tag{2}$$

The main thread (1) represents the percentage of work from time *t* to *t* + *dt*.

$$V(\theta) = \frac{V(t)}{V_0} \tag{3}$$

where V_0 is the volume up to the height h_0:

$$V_0 = \frac{\pi D^2 h_0}{4} \tag{4}$$

In this case, we introduce time without dimension θ by the following formula:

$$\theta = \frac{t}{t_1} \tag{5}$$

where t_1 is the average residence time of the flow particles in the apparatus:

$$t_1 = \frac{V}{v} \tag{6}$$

Equation (2) can now be reduced to:

$$dp = \frac{dg}{g} = \frac{vV(t)dt}{g} = v\frac{V_0 V(t)dt}{V_0}\frac{1}{g}\frac{t_1 dt}{t_1} = \frac{vV_0 t_1}{g}V(\theta)d\theta = \frac{vV_0\frac{V}{v}}{g}V(\theta)d\theta = V(\theta)d\theta \tag{7}$$

The total amount of added solvent is determined by the following expression:

$$g = v\int_0^\infty V(t)dt \tag{8}$$

In this case, the following expression follows from Eqs. (2), (7):

$$V(\theta) = \frac{V(t)}{\int_0^\infty V(t)dt} \tag{9}$$

This expression gives a standardized *V*-shaped curve (Fig. 2).

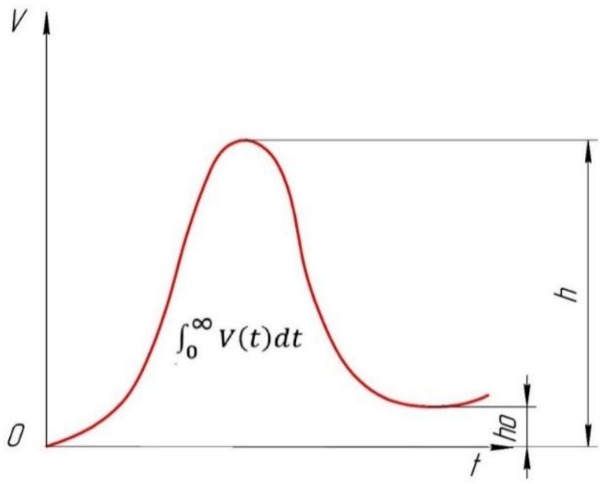

Fig. 2. ***Graph of the liquid flow in the Soxhlet.***

Thus, the following conclusions can be drawn that, if necessary, the time for the flow particles to be in the apparatus is not enough to complete the extraction process, which depends on the efficiency of the entire mass transfer process. Therefore, it is important to take into account the real structure of the phase flow in the apparatus, using model expressions about the internal structure of flows [30-34].

The time required for the solvent to remain in the Soxhlet is important during the extraction process. The description of the structure of the flows of metabolic processes also means that it allows you to determine the movement and distribution of substances in these flows. Therefore, in the Soxhlet, we wrote a hydrodynamic model of flows in the form of equations reflecting the change in time in the apparatus.

2. Acceleration of the extraction process

In solid-liquid systems, the extraction process is much slower, since the rate of permeability of the substance in the solid phase is several times lower than the rate of transfer of the substance in the liquid phase. As a result, the process of extracting the required component from solids takes a long time. Therefore, a number of methods have been proposed to accelerate the extraction of solids. Various methods are used to accelerate the transfer of substances [7-18]:

a) transverse mechanical vibrations;
b) vibration;
d) vibration (pulsation) of the fluid passing through the formation;
e) ultrasonic action on a mixture of solid and liquid substances (pulp);
f) the formation of electric lightning in the liquid;
j) periodic change in fluid flow.

In addition, the use of a boiling solvent in a vacuum and the application of electromagnetic field forces are also recommended.

Under the influence of mechanical vibrations (transverse vibration, vibration, pulsation), the rotation speed of solid particles of the liquid increases, the thickness of the boundary layer on the surface of the solid phase decreases, the contact surface between the phases increases, and the zones of inertia disappear. remains, which leads mainly to external diffusion acceleration [1-5].

If the densities of the solvent and the component in the liquid phase are close to each other, the use of the solvent by boiling in vacuum has a number of advantages [9]. The resulting vapor bubbles at the same speed spread throughout the entire volume of the layer and create the same conditions in all parts of the layer. In this process, there is a new phase (vapor bubbles). As a result, the relative motions of the solid and liquid are accelerated. The main reason for the acceleration of extraction due to boiling of the solvent is an increase in the active surface of solid particles. The acceleration of the extraction of solids under the action of an electromagnetic field can be explained as follows. Under the influence of electromagnetic forces, the separating component and solvent molecules are polarized, and the dielectric constant of the liquid phase increases. As a result, the thickness of the boundary layer on the surface of solid particles decreases, and the coefficient of internal diffusion in the solid phase increases, which leads to an acceleration of the extraction process [43].

The method of accelerating the extraction process using electric lightning has several advantages. With this method, electrical energy is directly converted into vibrational energy of the fluid, which is a one-step process with great efficiency. Acoustic vibrations of any frequency and amplitude can occur in the liquid phase. If oscillations of high amplitude and low frequency are generated, the velocity of the liquid around the solid particle increases, which leads to a decrease in the external diffusion resistance. As a result, the extraction process is accelerated.

3. Installation of an ultrasonic generator on a Soxhlet extractor and power consumption

Due to the slow mass transfer process in the extractor, a lot of thermal energy is consumed. To evaporate the solvent, we generate heat energy through a 2 kW heater. The process takes 3 hours and consumes 6 kW of electricity. To reduce this consumption, we used an ultrasound generating device [8-16].

There are many types of ultrasonic generators, from which you should choose the one that is low frequency and low power consumption. Since the extractor has additional equipment, the energy consumption should not increase. With this in mind, we chose the “High Power Ultrasonic Generator” 40 kHz, 1.2 kW ultrasonic generator. The selected generator circuit is shown in Fig. 3.

When the ultrasonic generator values (frequency, power, etc.) are high, the Soxhlet vibrates. Strong vibration will cause the extractor to become unbalanced. A high-performance generator with a large extractor is recommended [8].

An ultrasound generator was selected and placed in the extractor (Fig. 4).

Using an ultrasonic generator, the process took 2 hours. This shows that the process has accelerated. Now let's calculate the energy consumption.

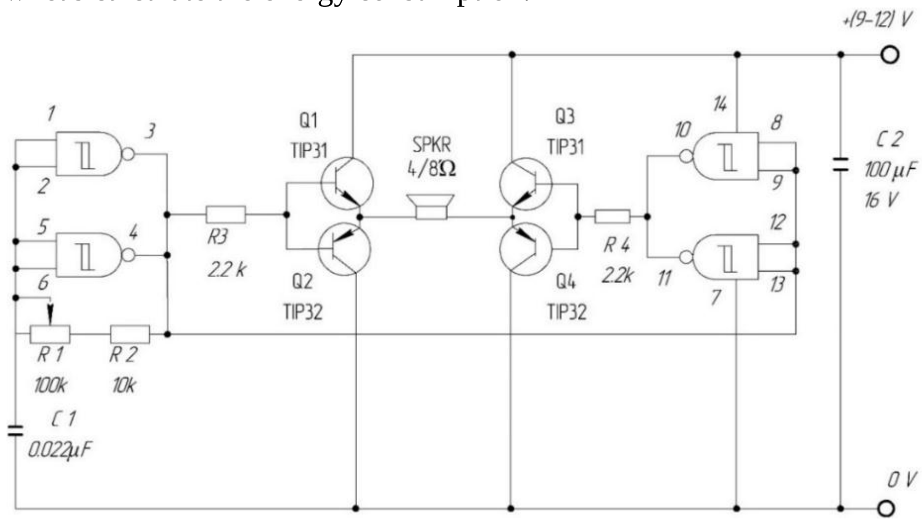

Fig. 3. ***Electroschematic view “High Power Ultrosonic Generator”.***

If the heater consumes 4 kW of energy in 2 hours, the ultrasonic generator consumes 1.2 kW of energy. Since we do not use the ultrasound generator regularly, it starts up every half hour. The total consumption is 5.2 kW. The energy consumption of the process is displayed versus time, as shown in Fig. 5.

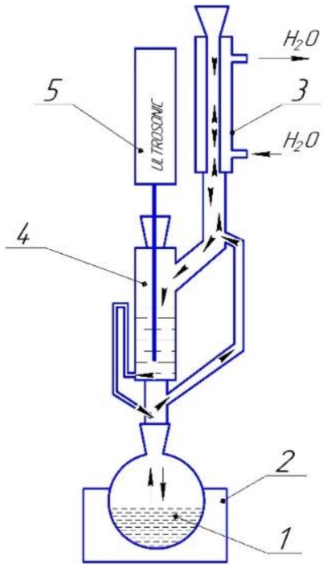

Fig. 4. ***Soxhlet extractor with ultrasonic apparatus.***
1 – solvent; 2 – heater; 3 – refrigerator; 4 – soxhlet; 5 – ultrosound generator.

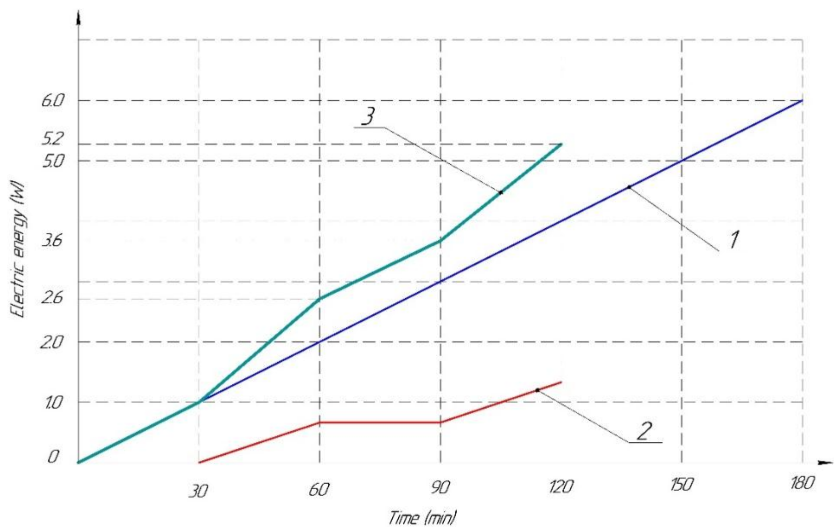

Fig. 5. ***Energy consumption of the extraction process.***
1 – electrical energy of the extractor; 2 – electrical energy of the ultrasonic generator; 3 – electrical energy of the ultrasonic extractor.

4. Experiments and their discussion

Basil leaves were selected for the study. We observed the separation of biologically active substances from the selected basil leaves in the extractor. The solvent was added to 1000 ml of a mixture of 40% alcohol. An experimental experiment was carried out for 1 hour to evaluate the process. Then the ultrasonic generator was compared with the connected position (Fig. 6). We have determined the amount of emitted substance in% of the concentration in the solution. A proportional determination method was used, that is, the ratio of the amount of substance in the separated solution to its volume.

The temperature rise only increased from 25 to 35 ° C for the extraction process. However, temperature did not have a statistically significant effect on the formation of anthocyanins and phenolic compounds. Active antioxidants measured by DPPH analysis did not differ in temperature rise for both processes..

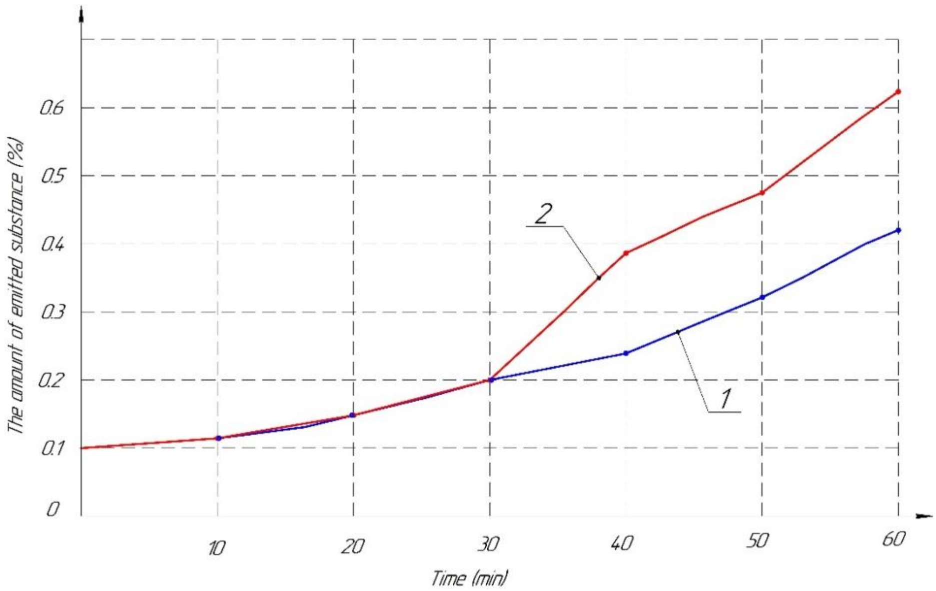

Fig. 6. ***The quantity of substances extracted from the basilica lists.***
1 – extractor separation; 2 – separation using ultrasound.

The rectification process was used to separate the separated substances from the solution. This process was performed in the same way for the extract recovered in both cases. The results of the extraction showed that when using ultrasound, 1.2 times more substances were released..

Conclusion

The results show that the process sped up after 1 hour when the ultrasonic generator was turned on. It has been proven that the use of this method in manufacturing can lead to a dramatic increase in productivity. However, the question arises whether ultrasound has an enzymatic effect on basil leaf extract.

The effect of ultrasound on the reduction of solids can be explained as follows. Under the action of ultrasound, the phenomenon of cavitation arises, which accelerates the movement of small flows in the pores of a solid, which leads to a change in the distribution of matter in the solid phase.

The influence of heating the medium and its mixing on the extraction process in an ultrasonic field is insignificant. Thus, ultrasound mainly accelerates the permeability of the substance in the solid phase.

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