

ANNOTATION

of the dissertation for the doctor of philosophy (PhD) degree
in specialty 6D072400 - "Technological machines and equipment"

Velyamov Shukhrat Massimzhanovich

"Development of equipment for the production of pectin from red beet"

The relevance of the research. The high growth in demand for natural biologically active substances in connection with the deterioration of the environmental situation in cities-megalopolises determines the task for technologists and designers to create new equipment that allows to effectively isolating target components with high functional properties from the products of the agro-industrial complex.

The well-known functional properties of pectin are of great interest, and it makes sense to develop the need for its daily consumption through the introduction of new equipment that allows the production of pectin (or pectin extract) and the creation of new recipes for everyday products enriched with it.

Most of the designs of equipment for the extraction of pectin from vegetable raw materials have a number of significant disadvantages, in particular, the complexity of the designs, the cumbersomeness of equipment and technological schemes, and high operating costs. The existing equipment for extraction is focused on technologies using aggressive environments of acids and alkalis, which excludes its use directly at the fruit and vegetable processing plant, and the creation of remote conditions leads to the need for preliminary procurement of raw materials, which is not profitable for producers.

An alternative way of solving this problem is the development of equipment - an extractor of plant raw materials, which allows the extraction of pectin by a biotechnological method, which is absolutely safe. One of such biotechnological methods of obtaining pectin (pectin extract) was developed and patented in the Republic of Kazakhstan by employees of Kazakh research institute of processing and food industry - patent of the Republic of Kazakhstan No. 29264. Also, a draft standard of the enterprise "Concentrate of pectin extract obtained from beet and carrot pomace" was developed, which passed the examination in the JSC "National Center for Expertise and Certification" and received an expert opinion No. 11/1 with the assignment of a number - ST 103847-1910-LLP-01-2014.

Today, for the successful implementation of the above-mentioned domestic technology, there is a question of intensifying this technology through the development of effective and inexpensive equipment that can be used in small and medium-sized enterprises for processing fruits and vegetables, there are more than 180 of them in the Republic of Kazakhstan.

It should be noted that the existing equipment for the fermentation of pectin substances is distinguished by the extensive process and low yield of the final product. Enzymatic action alone is not enough for the effective extraction of pectin,

which constitutes the cell structure of plant materials. As shown by previous experiments, when fermentation of pectin substances on standard equipment, the yield of pectin does not even reach 60%. In this regard, it is urgent to develop a technical solution that allows to increase the productivity of equipment for extraction and the intensity of the process of enzymatic extraction of pectin through the use of an ultrasonic generator and a high-speed mixer.

Research objects: technological equipment equipped with an ultrasonic generator and a high-speed stirrer.

Subject of research: technological process of enzymatic extraction of pectin, the regularity of the effect of ultrasonic action on plant raw materials and active mixing of the extractant during enzymatic extraction of pectin.

Purpose of the research: increasing the productivity and efficiency of the extractor of plant raw materials for obtaining pectin (pectin-containing extract) of table beet by the enzymatic method, development of a universal design of the extractor, equipped with an ultrasonic generator and a high-speed propeller-type stirrer, methods for its calculation and recommendations for use.

Scientific novelty of research:

- a mathematical model of the process of enzymatic extraction of pectin from plant raw materials has been developed, which allows calculating the optimal design parameters of an extractor equipped with an ultrasonic generator and a high-speed propeller-type stirrer.

- the main kinetic regularities of the process of enzymatic extraction of pectin from vegetable raw materials were established using the example of pomace of beetroot;

- the principles of creating a resource-saving technology for the processing of secondary plant raw materials - pomace of table beet, aimed at intensifying the process of obtaining the finished product;

The practical value of the research. The design of an extractor of plant raw materials, protected by the RK patent No. 33150, has been developed.

A method for calculating a plant raw material extractor equipped with an ultrasonic generator and a high-speed stirrer, designed for the extraction of pectin by an enzymatic method, has been developed.

Publications. On the topic of the dissertation, 12 articles were published, of which 5 were in the materials of international conferences, 5 - in publications recommended by the Committee for quality assurance in education and science MES RK, 2 - in publications included in the RSCI database, 1 - in a publication indexed in international base of scientific journals Skopus - Bulgarian Journal of Agricultural Science with 38th percentile (quartile - Q3) in the direction "Agricultural and biological sciences", 1 patent of the Republic of Kazakhstan.

The materials of the articles cover the main content of the dissertation, the work, in addition to the main research area, was carried out at the junction with such areas as "food technologies", "biotechnology", "processing of agricultural raw materials" and journals where the main results of the work are published, selected for the effective dissemination of the knowledge gained.

The introduction presents an assessment of the current state of the scientific

problem being solved, the basis and initial data for the development of the topic, the rationale for the need for research work, information about the planned scientific and technical level of development and metrological support of the dissertation, the relevance and novelty of the topic, the relationship of this work with other scientific - research work, purpose, object and subject, research objectives, methodological basis, provisions for defense, practical value and approbation of practical results.

The first section examines the current state and development trends of technology and technology for the production and use of pectin in functional nutrition.

The development of equipment for the process of enzymatic extraction of pectin from table beet makes sense if the country has the required amount of raw materials, the analysis of the data showed that stable production of table beet is developing in Kazakhstan, which has been increasing in recent years, i.e. the republic has a high raw material potential in this area.

When developing equipment for the extraction of pectin from plant materials, it is necessary to use modern methods of intensification, since, as shown by the data on the accumulation of pectin in beetroot, it can be seen that most of it is directly the structure of the cell, which must be destroyed by mechanical action.

The analysis of existing designs of extractors for plant raw materials showed that in Kazakhstan there are no analogues in such developments, and all existing designs have certain disadvantages, the most significant are: lack of elements that could increase the intensity of enzymatic extraction of pectin; high material and energy consumption due to the complexity of the design, which affects the cost of machines, and this, in turn, makes them unprofitable (expensive) for use in small processing plants.

To develop an extractor with hardware that allows to intensify the pectin extraction process, an analysis of existing methods for increasing the intensity of the extraction of biologically active substances from plant materials was carried out. As a result, it was revealed that the ultrasonic method for intensifying the yield of target components from plant raw materials is the most modern, but it requires additional studies of dependencies. The use of ultrasonic action on the plant cell will create the effect of cavitation in the cell of plant raw materials, which will lead to its destruction; therefore, it makes sense to study the use of an ultrasonic generator in the extractor design.

It should also be noted that in order to intensify the enzymatic extraction of pectin, it is necessary to ensure the uniformity of the processes of heat and mass transfer in an extractant medium with a low viscosity, in this regard, propeller mixers are used for intensive mixing of low-viscosity liquids, stirring up sediments containing up to 10% of the solid phase with particle sizes up to 0.15 mm, are sufficiently effective for mixing the extractant.

The research tasks were formulated based on the analysis carried out.

In the second section, based on the mass of plant materials and the volume of the extractant, the calculated dependences are given to determine the overall dimensions of the extractor. The substantiation of the method for calculating the

geometric characteristics and hardware equipment of the plant raw material extractor is presented.

The technique allows calculating the volume of the sieve section for loading plant raw materials, the required volume of the bath for the extractant, the location of the key hardware, as well as other necessary geometrical characteristics of the extractor.

In section also presented methods for calculating the power of the mixing device, ultrasonic emitter and heating elements.

The third section presents research methods and substantiation of operating modes of an extractor for plant raw materials using an ultrasonic generator and a mechanical stirrer.

A plan for conducting an experiment of the main characteristics of the extractor hardware (ultrasonic intensity and stirring frequency) has been determined. Methods of carrying out the process of enzymatic extraction of pectin from plant raw materials, studying the main functional parameters of the obtained pectin extract are presented. For experimental research, the instruments of the research laboratory "Biotechnology, quality and food safety" of the Kazakh research institute of processing and food industry were used, verified in the established order.

Rational operating modes of an extractor of plant raw materials equipped with an ultrasonic generator and a paddle stirrer have been substantiated experimentally. In particular, the influence of ultrasonic action on plant raw materials and active mixing of the extractant on the kinetics of pectin extraction from beetroot was studied. The experiments have shown the high efficiency of the use of an ultrasonic generator and a paddle mixer in the enzymatic extraction of pectin from plant raw materials.

As a result of multivariate statistical analysis, for the first time, the problem of optimizing the range of variation of the input parameters of the operating mode of the extractor intended for enzymatic extraction using ultrasonic action on plant raw materials and active mixing of the extractant with a propeller-type paddle mixer (rotation frequency of the mixing device – $3.3 \dots 16.6 \text{ s}^{-1}$; intensity of exposure to ultrasound - $50 \dots 150 \text{ kW} / \text{m}^2$; exposure (process duration) – $3.6 \cdot 10^3 \dots 18.0 \cdot 10^3 \text{ s}$).

The fourth section presents a mathematical model of the process of enzymatic extraction of pectin flowing in the developed design of the extractor.

The analysis of the process of enzymatic extraction of pectin has been carried out. In an ultrasonic field, along with large-scale acoustic flows, small-scale vortex flows appear at the interfaces, characterized by significant velocity gradients, energy dissipation, and local heating of the liquid. These factors accelerate the diffusion of macromolecules as a result of turbulent diffusion and a decrease in solution viscosity.

The increase in the extraction rate is explained by a change in the diffusion resistance of the boundary layer, the viscosity of which depends on the solubility of the extracted macromolecules and their intermolecular interaction.

Stirring of the extractant affects the increase in the yield of pectin due to its "leaching" from the plant raw material in the grid. With an increase in the stirring activity, external diffusion sharply increases (mass transfer from the surface of a particle of plant material to the extractant).

As a result of the studies carried out, the values of the extractor operating parameters (ultrasonic intensity and stirring frequency) for enzymatic extraction of pectin were determined, which ensure the maximum yield of pectin - 19-21% more efficiently and 2 hours faster than the standard method using fermenters.

A physical and mathematical model has been substantiated for describing the process of extracting pectin from plant raw materials in the proposed equipment under the complex action of ultrasound and active mixing. A criterial equation of the form is proposed:

$$\text{Nu}_D = 0.08\text{Re}^{0.5} \cdot \text{Pr}_D^{0.33} \cdot \text{Te}^{0.21} \cdot \text{Us}^{0.01},$$

which characterizes the intensity of extraction (the intensity of mass transfer in a solid-liquid system). Having calculated the right side, we thereby determine the value of the Nusselt criterion (Nu_D). Knowing Nu_D , we determine the mass transfer coefficient β . Then we calculate the transferred amount of the substance (pectin) to the extractant according to the mass transfer equation.

The results obtained make it possible to reveal the influence of individual factors on the yield of pectin during enzymatic extraction and can be used in the design and optimization of their work.

The fifth section presents the results of production tests, under the conditions of "Turgen Eco-Product" LLP, an experimental-industrial model of an extractor assembled on the basis of the developed calculation method for 1 kg of plant material and 15 liters of extractant. With continuous operation of the extractor for 1 shift (9 hours), 32 liters of pectin-containing extract were produced. The concentration of pectin in the total volume of the extract was 5.4 g / l. The obtained extract volume is sufficient for the production of 160 liters of fruit and vegetable enriched juice, and the proposed extractor model has shown its suitability for small and medium-sized enterprises for the production of natural fruit and vegetable juices.

The functional properties of the pectin extract samples obtained on the developed equipment have been studied. Under in vitro conditions, low-esterified pectin from beetroot has more pronounced reducing properties than the antioxidant drug emoxipin, which confirmed the possibility of using the obtained pectin extract as a dietary supplement for food.

The study of the main physical and chemical indicators and safety indicators obtained on the developed equipment samples of pectin extract. The content of pesticides, toxic elements and pathogenic microorganisms was not detected, or the indicators are within the permissible limits, which confirms the safety of the products obtained.

The calculation of the economic efficiency of the implementation of the proposed equipment has been carried out. The introduction of equipment for the processing of secondary raw materials will increase the income of processing enterprises by 4 386 222.88 tenge by expanding the range.

In the conclusion, brief conclusions are given on the results of dissertation research, an assessment of the completeness of solutions to the tasks posed, recommendations and initial data on the specific use of the results are developed, an

assessment of the technical and economic efficiency of implementation and the scientific level of the work performed in comparison with the best achievements in this area is given.