

The processes of obtaining particles of chitosan aerogels

Abstract

One of the tasks of the development of the chemical industry of the Russian Federation is the creation of innovative materials production facilities, which will potentially improve the scientific and technical potential of the country, attract investment in high-tech projects and increase competitiveness in the global market. According to the order dated 31.12.2020 3684-p, within the framework of the Program of Fundamental Scientific Research of the Russian Federation until 2030, one of the priorities is the development of compounds and materials with specified properties, innovative materials. Chitosan aerogels are innovative materials due to their unique properties and characteristics, renewable resource base and potential applications in various industries, for example, as hemostatic materials. Since there is a high demand for the production of hemostatic agents on the Russian market, the task of developing a technology for their production is relevant and significant in the Russian Federation.

In this work, processes and devices for the production of particles and microparticles of chitosan aerogels designed to stop bleeding from tissues and main vessels of varying severity are investigated. The main stages of obtaining chitosan aerogels are gel formation, solvent replacement and supercritical drying. The key characteristics of chitosan aerogel particles (high sorption capacity, porosity and specific surface area) are determined at the gelation stage, and therefore, the study of this process was the most in-depth.

The work was carried out within the framework of agreement No. 075-15-2020-792 (unique identifier: RF-190220X0031) as part of the state assignment to the university on the topic "Nanobiotechnology in the diagnosis and therapy of socially significant diseases".

The aim of the study was to experimentally study and model processes and devices for producing particles of chitosan aerogels, including those containing active pharmaceutical substances.

Tasks:

1. Experimental study of the processes of obtaining chitosan aerogels in the form of particles and microparticles, with varying the main parameters of the process.
2. Theoretical and experimental study of the processes of introducing active pharmaceutical substances into the pores of chitosan aerogels using supercritical fluids.
3. Mathematical modeling of processes and devices for obtaining chitosan aerogels.

4. Conceptual design of the technological scheme for the production of chitosan aerogel particles.

5. Economic calculation of the processes of obtaining particles of chitosan aerogels.

Scientific novelty. The main dependences of the characteristics of particles of chitosan aerogels obtained by the drip method, the method of spraying chitosan solution through a nozzle and the oil-emulsion method followed by solvent replacement and supercritical drying on the parameters of the process of their production based on a set of experiments and comprehensive analytical studies have been revealed.

The mechanisms of the adsorption process of a number of active pharmaceutical substances (lidocaine hydrochloride and erythromycin) into the pores of chitosan aerogel particles are theoretically substantiated, depending on the method of the technological process used (introduction at the solvent replacement stage, supercritical adsorption) and its parameters.

With the help of tools and methods of computational fluid dynamics, a model describing the movement of liquid flows in a receiving tank for the process of obtaining chitosan gel particles has been implemented. An algorithm has been developed for calculating the material balance of the solvent replacement process for a given productivity, reducing raw material costs, taking into account the restrictions imposed by the remaining stages of the process.

A conceptual design of the technological scheme of the process of obtaining chitosan aerogel particles has been developed, taking into account all stages of the process (preparation of initial solutions, gelation, solvent replacement and supercritical drying), taking into account the economics of the process.

Practical significance. The methods of the processes of introduction of active pharmaceutical substances using supercritical fluid technologies have been developed, which can be used in the production of local hemostatic agents with therapeutic effect.

The obtained particles of chitosan aerogels can be used as local hemostatic agents for the relief of arterial and venous bleeding in combination with the therapy of tissue damage. Technological conditions have been developed for the production of chitosan aerogels in the form of particles and Laboratory regulations for the technology of their production (TY 21.20.24-035-02066492-2023, Laboratory Regulation No. 26.43-099/B/PR 189 OD.444/2023).

An installation has been assembled to produce chitosan-based gel particles by spraying a chitosan solution through a pneumatic nozzle followed by gelation in a receiving tank (KNOW-HOW has been registered on the design of the developed installation).

A patent application has been filed for "Hemostatic particles based on chitosan with embedded active substances and a method for their preparation" (Application No. 2023113337 dated 23.05.2023).

A software module has been developed that allows for the conceptual design of a technological scheme for the production of chitosan aerogel particles, taking into account all stages of the process and their economic characteristics.

The main provisions for the defense.

– The processes of obtaining chitosan aerogel particles by drip method, by spraying chitosan solution through a nozzle followed by gelation and oil-emulsion method with subsequent solvent replacement and supercritical drying with specified characteristics. The dependences of the obtained particles and microparticles of chitosan aerogel on the variable parameters of their production process. Experimentally proven use of chitosan aerogel particles and microparticles as local hemostatic agents to stop bleeding of varying intensity, including arterial bleeding.

– The results of theoretical and experimental studies of the processes of introducing active pharmaceutical substances into the pores of chitosan aerogel particles by introducing at the solvent replacement stage and supercritical adsorption with varying process parameters. Theoretical substantiation of the mechanisms of mass transfer of active pharmaceutical substances adsorbed into the pores of chitosan aerogel particles, depending on the method of the technological process used and its parameters.

– A mathematical model of the hydrodynamics of the fluid flow inside the receiving tank for the process of obtaining chitosan gel particles. An algorithm for calculating the material balance of the solvent replacement process in the pores of chitosan gel particles for a given performance, taking into account the limitations imposed by the remaining stages of the process. A calculation module that allows for the conceptual design of a technological scheme for the production of chitosan aerogel particles, taking into account all stages of the process and economic costs, which can be used to produce batches of chitosan aerogel particles of various volumes.