METHODS FOR IMPROVING HEAT EXCHANGE EQUIPMENT IN CITRIC ACID PRODUCTION

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Abstract
This paper analyses the main approaches to improving heat exchange equipment used in the process of citric acid production by the microbiological method using fungi of the genus Aspergillus niger. Special attention is paid to modern designs of shell-and-tube heat exchangers, their technical advantages and disadvantages.
Keywords: *citric acid, shell-and-tube heat exchanger, aspergillus niger, energy efficiency*

Introduction. Citric acid is an important organic compound widely used in the food, pharmaceutical and chemical industries [1]. The main method of its production is microbiological synthesis using fungi of the genus *Aspergillus niger*. To ensure high production productivity, it is necessary to optimize all stages, in particular heat exchange processes, which play a key role in stabilizing the technological process [2].

Citric acid production is currently based on deeply optimized biotechnological processes, automated bioreactors and effective purification systems. Improvements in sterilization methods, pH and temperature control significantly increase yield and reduce cost. New generation heat exchangers allow to ensure stable process conditions with minimal energy consumption.

To ensure a stable thermal regime, shell-and-tube heat exchangers are widely used; however, standard designs do not always provide uniform cooling of the medium or sufficient heat transfer intensity under high-viscosity conditions.

The aim of this work is to analyse the improvement of shell-and-tube heat exchanger designs by implementing new engineering solutions that enhance the efficiency of heat exchange processes, particularly in the technological processes of citric acid production.

Materials and Methods. Analytical studies on the modification and improvement of heat exchange equipment in Ukraine and worldwide. For the analysis of heat exchange equipment improvements, methods of computer modelling and mathematical analysis of heat exchange processes were used. The effectiveness of various heat exchanger designs was studied based on the results of experiments conducted at enterprises involved in citric acid production, as well as using open databases of industrial installations.

Results and Discussion. An important aspect in enhancing heat exchange efficiency is the use of advanced methods for modifying heat exchanger materials, particularly the application of titanium and stainless-steel alloys, which possess high corrosion resistance and can withstand the aggressive environments typical of citric acid production. The use of such materials significantly reduces maintenance costs and extends the operational lifespan of the equipment.

Another crucial aspect is the improvement of heat exchanger designs in terms of the geometry of heat exchange surfaces. The use of helical fins or variable tube diameters helps to enhance flow turbulence and, consequently, improve heat transfer efficiency.

The modification of heat exchange equipment is based on the use of modern engineering approaches, computer modelling, and experimental data from industrial practice. Particular attention is given to the implementation of energy-efficient designs, the use of new materials with enhanced corrosion resistance, as well as the improvement of the internal geometry of heat exchange devices to enhance flow turbulence [3]. Various engineering solutions enable higher heat transfer coefficients, reduced hydraulic resistance, increased reliability in aggressive environments, and minimized energy consumption.

Studies of heat exchange processes in citric acid production show that the use of shell-and-tube heat exchangers is one of the most effective approaches to ensuring a stable temperature regime [4]. Due to their design, these devices provide a high heat transfer coefficient, reliability during long-term use, and the ability to operate with aggressive environments. An important aspect is the proper selection of construction materials, which guarantees corrosion resistance and sanitary safety.

Research by the authors [5] showed that changing the geometry of the tube bundle, particularly through the use of helical fins, reduces the tendency to fouling and increases heat exchange efficiency in shell-and-tube heat exchangers.

The study [6] proposed an optimization strategy for the configuration of shell-and-tube heat exchangers with segmental baffles, combining genetic algorithms and particle swarm methods. The results showed improved heat transfer and reduced pressure losses.

The authors [7] investigated the use of new types of baffles, specifically "flower baffles," in shell-and-tube heat exchangers. Experimental results showed a 31.7% increase in the heat transfer coefficient compared to traditional segmental baffles.

Conclusion. The improvement of heat exchanger designs, particularly shell-and-tube type, is an effective way to enhance energy efficiency and productivity in production. Modern technical solutions allow for stable temperature control, reduced energy consumption, and improved sanitary safety of the process [8].

Thus, further research and the implementation of cutting-edge engineering developments in heat exchange equipment design is a promising direction for the development of citric acid biotechnology production.

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