CLASSIFICATION OF TECHNOLOGICAL EQUIPMENT FOR HOMOGENIZATION

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Анотація. Робота присвячена аналізу технологічного обладнання, яке використовують для гомогенізації молока та молочних продуктів з метою визначення найбільш ефективнішого, що дає змогу отримати якісний продукт.

Homogenization refers to a technological process designed to create a uniform mixture from components that are normally immiscible. This technique finds applications in various industries, including agriculture, chemical manufacturing, food processing, pharmaceuticals, and cosmetics. However, its most widespread use is in the dairy sector, particularly in the production of milk-based products. The equipment used for this purpose is known as a homogenizer [1].

In the dairy industry, valve-type homogenizers are predominantly employed. The conventional design of these devices includes a plunger pump that generates high pressure and a two-stage system of homogenizing valves held against their seats by springs. The valve homogenizer operates in the following manner: liquid enters the chamber beneath the valve, and the flow pressure is counteracted by a back-pressure assembly consisting of a spring-loaded rod and a compression nut, which helps to maintain a narrow clearance between the valve and its seat. Due to the spring force, the valve remains pressed against the seat. As pressure increases, the valve assumes a floating position, and the emulsion flows through a thin annular gap (ranging from 0.05 to 2.5 mm), undergoing homogenization in the process.

An analysis of valve homogenizers reveals several drawbacks: they are large and heavy, require significant amounts of metal for construction, consume a high level of energy, and experience rapid wear of working parts, especially the valve surfaces. Additionally, the cost of such machines can be relatively high (approximately 30,000 UAH for a unit with a throughput of 5,000 L/h). It should be noted that foreign counterparts do not offer significant advantages in these areas.

Based on studies of multicomponent mixture dispersion through adiabatic boiling, a new category of homogenizing devices has been developed—vacuum homogenizers. In this system, milk is preheated to 80°C and delivered into a vacuum chamber maintained at 0.01–0.02 MPa by a vacuum pump.

Despite their benefits, vacuum homogenizers are not capable of reducing the average fat globule diameter below 2.0 microns. Nevertheless, they offer several advantages, such as lowering product acidity, increasing heat resistance, removing dissolved gases and odors, and decreasing microbial load.

Ultrasonic homogenizers are also widely used to disperse the fat phase of milk, leveraging the phenomenon of acoustic cavitation. These devices can produce not only emulsions but also fine suspensions. The breakdown of particles occurs in two phases: microcracks develop upon particle collision, followed by the propagation and expansion of these cracks under the influence of cavitation shock waves. Ultrasonic vibrations are typically generated using hydrodynamic or electromechanical methods (e.g., electromagnetic, magnetostrictive, or piezoelectric transducers).

One key advantage of ultrasonic homogenization lies in the ability to finely control the process by adjusting the frequency and amplitude of the sound waves. Additionally, ultrasonication can sterilize milk at ambient temperature by inactivating microorganisms while preserving heat-sensitive nutrients such as vitamins.

Another category of homogenizing equipment includes rotor-pulsation apparatuses (RPA). These operate by feeding milk under pressure into a rotating chamber. As the rotor spins, its channels alternately align and misalign with those in the stator, causing periodic pressure fluctuations. When the channels are blocked, pressure rises; when they align, it drops rapidly.

However, milk processed in RPAs tends to contain a broad distribution of fat globule sizes, including relatively large particles, which can negatively affect the quality and consistency of certain dairy products.

Jet-impact homogenizers operate on the principle of directing a high-speed jet of milk onto a flat deflector plate. Fat breakdown occurs both within the emulsifying channel-due to turbulent eddies and pulsations that create shear gradients—and upon impact with the plate, where velocity differentials further contribute to fat globule fragmentation.

In counterflow jet homogenizers, milk is forced under pressure through two opposing nozzles aligned along a common axis. Homogenization takes place in the emulsifying channel due to rapid velocity changes, upon exiting the channel, and especially at the point of jet collision. When jets with equal velocity and spray characteristics meet, significant shear gradients arise, inducing stresses that deform and rupture the fat globules. This design offers energy savings due to the efficient mechanism of particle disruption.

Nevertheless, this method is not without its downsides. Counterflow jet homogenizers often suffer from excessive foam formation and remain largely impractical for industrial use.

A more recent innovation in this field is the pulse-type milk homogenizer. Research has shown that intense, intermittent mechanical impulses can effectively fragment the dispersed phase of an emulsion.

Tests of the pulsed homogenizer indicate that it generates pressure fluctuations up to 1.5 MPa at a frequency of 50 Hz. After treatment, the average size of fat globules in the processed milk is approximately 0.5 microns.

In conclusion, analysis suggests that pulse homogenizers offer a highly promising solution for dairy homogenization. They provide superior homogenization performance while maintaining relatively low energy consumption.

References:

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