ANALYSIS OF THE EFFICIENCY OF STIRRING THE DEEP CULTURE MEDIUM OF NATIVE MICROBIAL SUSPENSION FOR OBTAINING LACTOBACTERIN

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Abstract

This article examines the features of homogenization using different types of mixers: blade, six-blade and open turbine. Using computer modeling with SolidWorks software and the addition of Flow Simulation, mixing processes and the influence of equipment types on the dynamics of a two-component fluid are investigated.

Keywords: *fermenter, lactobacteria, mixing, hydrodynamics*

Introduction. Deep cultivation is one of the key methods of microbiological production, which allows to intensify the cultivation of microorganisms by controlling the parameters of the environment. The efficiency of this process largely depends on the uniformity of mixing of the culture liquid, which affects the distribution of nutrients, gas exchange, thermoregulation and recovery of metabolites.

Insufficient homogenization of the medium can lead to biomass stratification, the formation of anaerobic zones and a decrease in the productivity of biosynthesis. On the contrary, increased mechanical or pneumatic action can disrupt the structure of microbial groups, inhibiting their metabolic activity. Considering that lactobacterin as a biopreparation requires a high concentration of viable cells and bioactive metabolites, optimization of mixing modes becomes a critical stage of the technology. [1]

The authors of [2] focused on the design and scaling of industrial production of lactic acid by fermentation of whey permeate, using standard methodological approaches. The Rushton turbine mixer (RTB) demonstrated the highest, and the four-bladed hydrofoil Lightnin A315 (LA315) demonstrated the lowest torque at the same specific power P/Vw of 2.8 kW m^{-3}, with mixing speeds of 1.33 and 2.5 s^{-1}, respectively.

The study [3] presented the hydrodynamics simulation of a bioreactor with standard types of open turbine mixers in the ANSYS environment. It was found that in the proposed device its vortex is almost not formed: at a rotation speed of 400 rpm, the depth is 0.06 m, and at 600 rpm - only 0.012 m.

The researchers [4] studied the hydrodynamic properties of the enzyme using ANSYS FLUENT 2021 R1 and verified them experimentally. The obtained model data agree well with the experimental results: the flow shapes were as follows, and the mixing time error was on average 7.9%. With increasing mixing speed, the torque, power, and shear stress increased, while the mixing time decreased.

The aim of the work is to analyze the efficiency of mixing a two-component culture liquid with three different types of mixing devices mounted on a vertical shaft.

Materials and methods. To calculate the process, the stage of cultivation of a native microbial suspension, a strain of lactobacilli Lactobacillus plantarum, which is obtained by deep cultivation of lactobacilli in a fermenter, was taken as an example.

From the geometric parameters of the fermenter, the equipment was selected according to GOST 20680-2002, GOST 6533-78, with a total volume of 0.25 m3. The geometric dimensions of the mixers used during the simulation were selected according to OST 26-01-1245-83.

Results and discussion. After building 3D models in the SolidWorks V23 software and the Flow Simulation application, the mixing process was simulated with three different mixers with a given standardized mixing frequency of 3.33 s-1. Mixing time 5-60 seconds.

When using a paddle mixer, the following dynamics of mixing of liquid components along the central cross section were observed (Fig. 1). Formation of a

V-shaped turbulent mixing flow directed horizontally upwards, with minimal mixing of the substance located in the bottom zone of the fermenter.

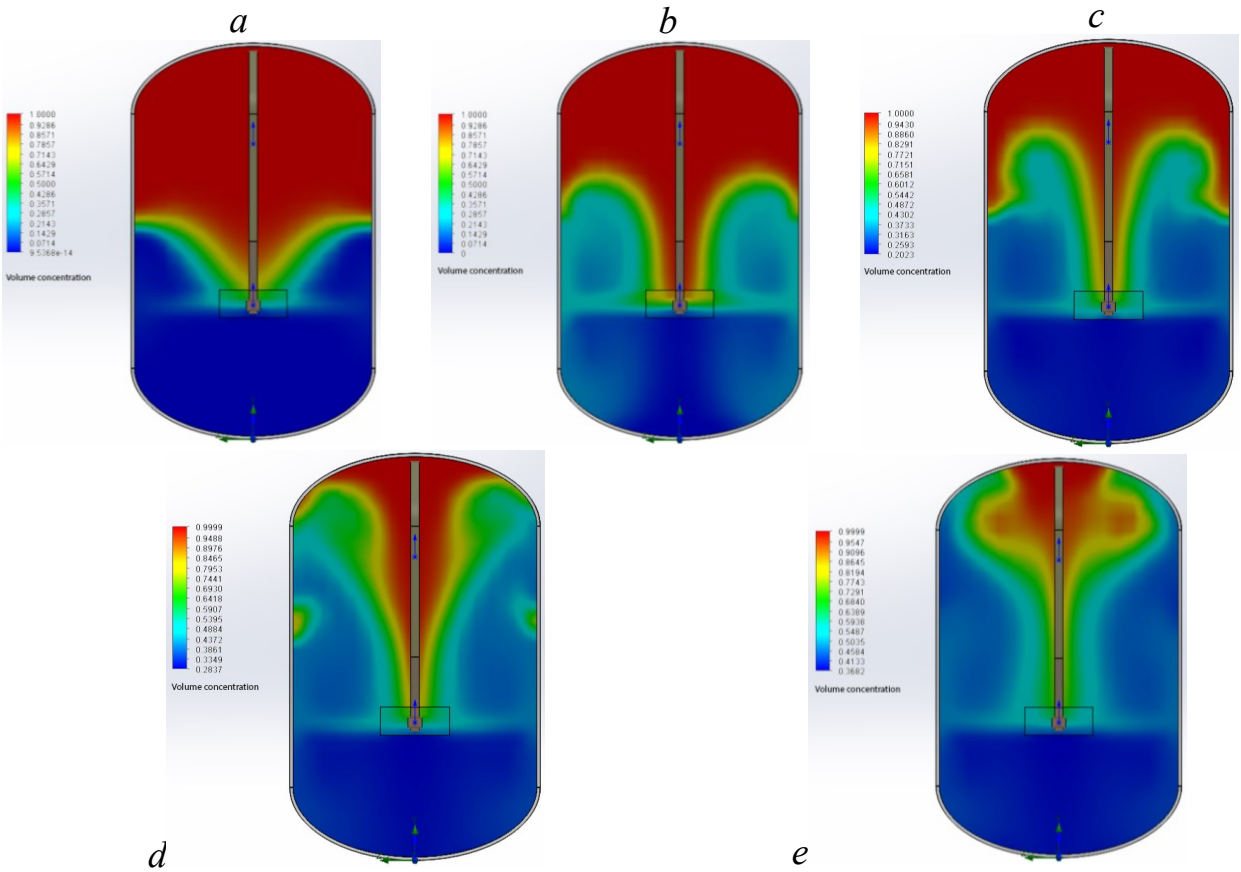


Fig. 1. Dynamics of mixing of liquid components with a paddle mixer: a – 5 seconds; b – 15 seconds; c – 30 seconds; d – 45 seconds; e –60 seconds.

When using a six-blade mixer, a significant increase in process efficiency is observed (Fig. 2). Due to the arrangement of the blades of this type of mixer at an angle of 45º, the substance close to the shaft of the structure is partially captured from the upper layers and redirected to the bottom of the fermenter, thereby creating an additional flow of substance from the lower layers of the solution.

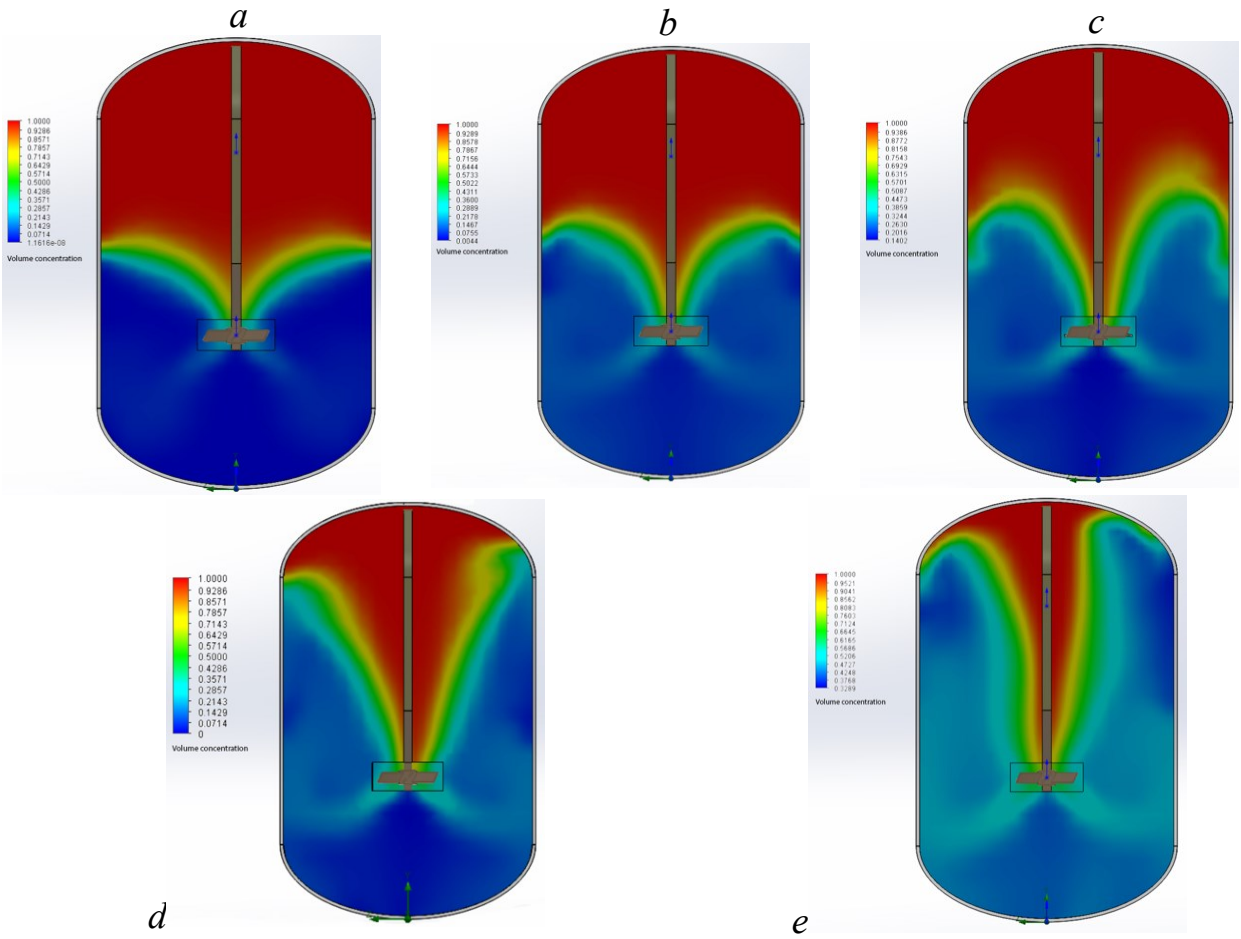


Fig. 2. Dynamics of mixing of liquid components when using a six-blade mixer: a – 5 seconds; b – 15 seconds; c – 30 seconds; d – 45 seconds; e –60 seconds.

When using a turbine open mixer, a completely different level of efficiency is observed (Fig. 3, 4). Under the same conditions and standardized characteristics, this type of mixing device was enough for 60 seconds to equilibrate the concentrations of the two-component solution by 87%.

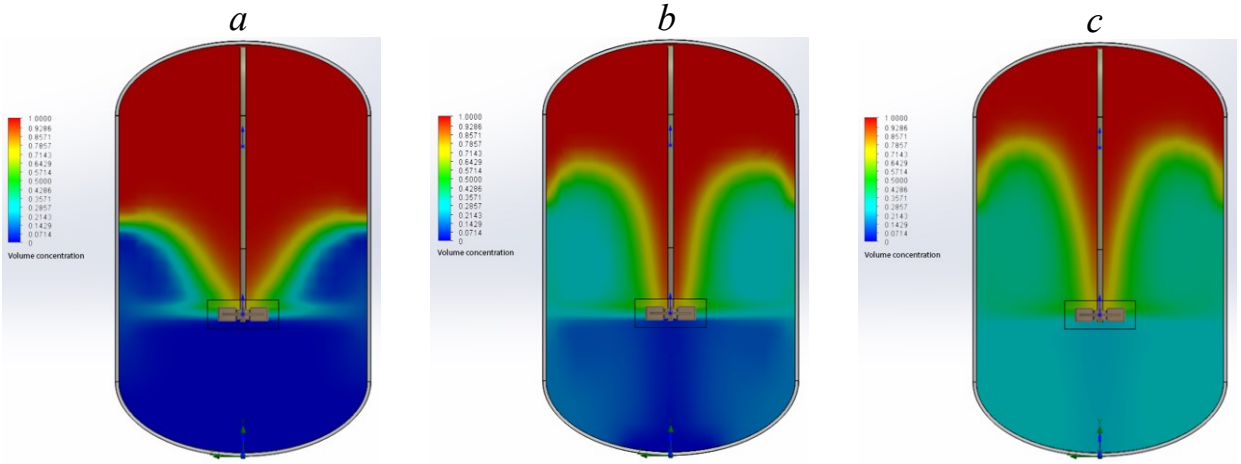
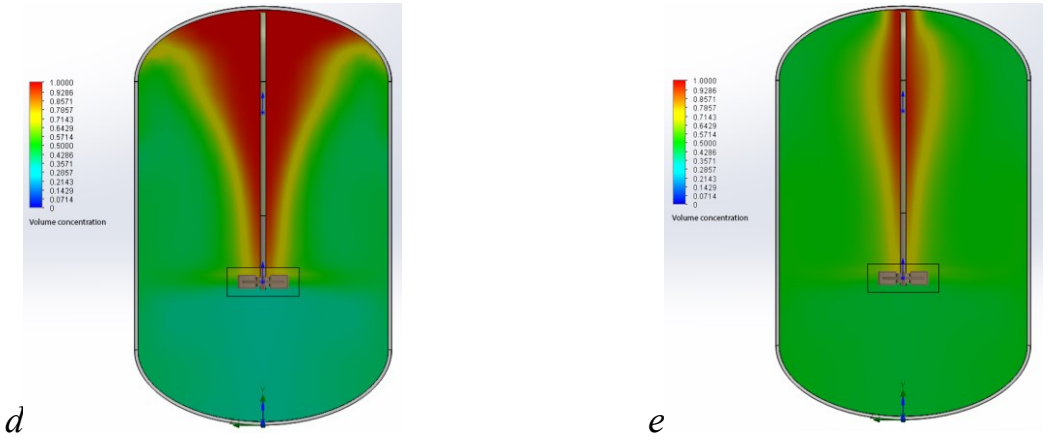


Fig. 3. Dynamics of mixing of liquid components with a turbine open mixer: a – 5 seconds; b – 15 seconds; c – 30 seconds.



d *e*

Fig. 4. Dynamics of mixing of liquid components with a turbine open mixer: d – 45 seconds; e – 60 seconds.

Conclusions. According to the results of the research, the specifics of the hydrodynamic characteristics of mixing solutions of the culture medium were established under the same initial physical and geometric conditions of the equipment, but with different types of stirrers.

Based on the obtained modelling results, it can be noted that the open turbine stirrer is the most efficient, in addition, the improvement and introduction of innovative solutions regarding the shape and type of the blade [3,5] will significantly increase the efficiency of the equipment.

References:

1. Cherepansky, V. V. Features of the technological process of producing a probiotic preparation based on lactobacilli / V. V. Cherepansky, N. M. Gregirchak / Scientific works of the National University of Food Technologies. - 2020. -Vol. 26, No. 3. - P. 45-59.

2. Mediboyina, M.K., Holden, N.M., O'Neill, S. et al. Upscale fermenter design for lactic acid production from cheese whey permeate focusing on impeller selection and energy optimization. J Food Sci Technol 59, 2263–2273 (2022). https://doi.org/10.1007/s13197-021-05239-6

3. Korobiichuk, I., Shybetskyi, V., Kostyk, S., Kalinina, M., & Tsytsiura, A. (2022). Ways to Reduce the Creation of Vortex During Homogenization of Liquid Products. In R. Szewczyk, C. Zieliński, & M. Kaliczyńska (Eds.), Automation 2022: New Solutions and Technologies for Automation, Robotics and Measurement Techniques (Vol. 1427, pp. 33). Cham: Springer. https://doi.org/10.1007/978-3-031-03502-9_33

4. Novia Novia, Jerry Hardian, Richard Sepriyadi Osman, Getari Kasmiarti, Hasanudin Hasanudin, & Hermansyah Hermansyah. (2023). Hydrodynamics Analysis of Mixing Process in Fermenter. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 109(1), 71–90. https://doi.org/10.37934/arfmts.109.1.7190

5. A. S. Ruzhanskyi, S. I. Kostyk (2023) Features of hydrodynamics when using an open turbine mixer with a special blade surface. http://conf.biotech.kpi.ua/article/view/304307