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STUDY OF THE ENCAPSULATION PROCESS USING PROTEIN AND POLYSACCHARIDE MATRICES

Ergashova Zilola Avaz kizi
doctoral student
Salijonova Shakhnozakhon Dilmurodovna
Doctor of Technical Sciences (DSc), Associate Professor
Ruzibaev Akbarali Tursinbayevich
Doctor of Technical Sciences (DSc), Professor
Tashkent Institute of Chemical Technology

Abstract. *Modern research confirms that functional nutrition, including foods enriched with probiotic microorganisms, is one of the key areas of innovation in food biotechnology. Probiotics are live microorganisms whose consumption in adequate amounts yields health benefits for the human digestive and immune systems. This work analyzes the mechanisms of incorporating probiotics into food products, the technological features of ensuring their viability, and the specific characteristics of the development of the functional nutrition market in Uzbekistan. In addition, the key challenges of introducing such products into the local food industry are discussed.*

Key words: *functional nutrition, food biotechnology, probiotic microorganisms, probiotic viability, food industry.*

Аннотация. *Современные исследования подтверждают, что функциональное питание, в том числе продукты, обогащённые пробиотическими микроорганизмами, является одним из ключевых направлений инноваций в пищевой биотехнологии. Пробиотики - живые микроорганизмы, употребление которых в адекватной дозе сопровождается положительными эффектами для пищеварительной и иммунной систем человека. Данная работа анализирует механизмы включения пробиотиков в пищевые продукты, технологические особенности обеспечения их жизнеспособности, а также особенности развития рынка функционального питания в Узбекистане. Кроме того, обсуждаются ключевые проблемы внедрения таких продуктов в местной пищевой промышленности.*

Ключевые слова: *функциональное питание, пищевая биотехнология, пробиотические микроорганизмы, жизнеспособность пробиотиков, пищевая промышленность.*

Probiotics are defined as live microorganisms that, when consumed in adequate amounts, confer health benefits to the host. Their role in maintaining gut microbiota homeostasis, modulating immune responses, and regulating metabolic processes has been extensively investigated in recent decades. The growing interest in probiotic supplements is driven by increasing knowledge of the human microbiota and advances in technologies for incorporating live microbial cultures into food products.

The global market for functional ingredients, including probiotics, has been steadily expanding: in 2025, its value was estimated at approximately USD 127.5 billion, and it is projected to reach USD 232.4 billion by 2034, with a compound annual growth rate (CAGR) [3] of approximately 6.9%. Among the various segments, probiotics account for the largest share (approximately 32%), driven by growing consumer demand for products that support gut and immune health.

The research methodology includes a critical analysis of scientific literature and experimental data, a comparative assessment of technological approaches to probiotic encapsulation, and an evaluation of the specific characteristics of the Uzbek market in the context of functional food production.

Probiotic viability is determined not only by the biological characteristics of the microorganisms but also by the conditions of technological processing and storage. To achieve the intended effects of functional foods, viable cells should be present at levels ranging from 10^6 to 10^9 colony-forming units (CFU) per serving at the time of consumption. This requires optimization of technological processes, including the control of temperature, moisture, pH, and interactions with the food matrix.

In Uzbekistan, research in the field of probiotic microbiology is conducted at the specialized Laboratory of Microbiology and Biotechnology of Probiotics at the Institute of Microbiology of the Academy of Sciences of the Republic of Uzbekistan. The laboratory focuses on the isolation of indigenous strains of lactic acid bacteria and the investigation of their properties [2].

The conventional incorporation of probiotic cultures into finished food products is often associated with a loss of viability due to thermal, mechanical, and acidic stresses. One promising approach to overcoming these limitations is microencapsulation the incorporation of live cultures into protective matrices, such as polysaccharides or proteins. This technology can substantially improve the stability and viability of probiotic cultures during food processing and storage, as well as during their passage through the gastrointestinal tract.

Recent studies have also highlighted a growing trend toward the development of non-heat-treated and non-dairy probiotic products, including fruit-based beverages, plant-based probiotic snacks, and functional bars. These products contribute to the

diversification of the functional food sector and offer new opportunities for consumer adoption [1].

Despite growing global demand, the functional food industry in Uzbekistan faces a number of specific challenges:

1. Limited local industrial infrastructure - the production of functional ingredients, including probiotics, currently lacks a sufficiently developed industrial infrastructure, which limits local value creation and supply-chain resilience.
2. Insufficient integration between research and industry - although scientific laboratories conduct research on probiotic strains and bioproducts, their translation into large-scale commercial food production remains limited due to insufficient investment and a lack of appropriate technological infrastructure and equipment.
3. Limited consumer awareness and knowledge - functional foods, particularly probiotic-enriched products, are often perceived by consumers as niche or relatively expensive products, which may hinder their widespread adoption in the domestic market.

In addition, extensive international research on dietary patterns and nutritional practices conducted by organizations such as the WHO has identified insufficient dietary balance and limited awareness of the principles of healthy nutrition among populations in different countries. These findings indirectly indicate both the potential for and the need to develop functional foods as one of the approaches to improving public health.

Functional foods, including probiotic-enriched products, demonstrate substantial scientific and commercial potential in the global market. Their successful development and implementation in Uzbekistan will require addressing the limitations of the existing industrial infrastructure, strengthening the integration of scientific research with industrial production, improving standardization and regulatory frameworks, and increasing consumer awareness of the potential benefits of functional foods. Addressing these challenges could contribute to improving the nutritional quality of the population and promoting the development of an innovative and competitive food industry.

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