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FERMENTATION-BASED MANUFACTURING OF POSTBIOTICS: FROM STRAIN SELECTION TO SHELF-STABLE INGREDIENT

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Abstract: Traditional probiotics are hindered by their poor ability to survive in acidic and bile-containing environments, by the need for strict storage conditions, and by inaccurate dosing. According to ISAPP, postbiotics are defined as inanimate microorganisms and/or their components that produce a health benefit and avoid these drawbacks. The present review offers a thorough summary of the fermentation-based manufacturing of postbiotics, covering the entire process from strain selection right through to the creation of a shelf-stable product, with reference to literature published between 2020 and 2026.
Keywords: postbiotics; fermentation; inactivation; downstream processing; bioactives.

Annotatsiya: An’anaviy probiotiklardan foydalanishda kislotali va o‘t suyuqligi mavjud muhitda yashab qolish qobiliyatining pastligi, saqlash sharoitlariga qat’iy talablar va dozalashdagi noaniqliklar kabi muammolar mavjud. ISAPP ta’rifiga ko‘ra, postbiotiklar — bu salomatlikka foyda keltiradigan hamda yuqorida qayd etilgan kamchiliklardan xoli bo‘lgan jonli bo‘lmagan mikroorganizmlar va/yoki ularning tarkibiy qismlaridir. Ushbu sharhda 2020–2026-yillar oralig‘ida chop etilgan ilmiy manbalarga tayangan holda, postbiotiklarni fermentatsiya usulida ishlab chiqarish jarayoni — shtammni tanlashdan boshlab toki uzoq muddat saqlashga yaroqli mahsulotni yaratishgacha bo‘lgan barcha bosqichlar — batafsil yoritilgan.
Kalit so‘zlar: postbiotiklar; fermentatsiya; inaktivatsiya; yakuniy qayta ishlash; bioaktivlar.

Аннотация: Эффективность традиционных пробиотиков ограничивается их низкой выживаемостью в кислой среде и в присутствии желчи, необходимостью соблюдения строгих условий хранения, а также сложностью точного дозирования. Согласно определению ISAPP, постбиотики представляют собой нежизнеспособные микроорганизмы и/или их компоненты, оказывающие благотворное влияние на здоровье и лишенные указанных недостатков. В данном обзоре представлен подробный анализ процессов производства постбиотиков методом ферментации — от выбора штамма до получения готового продукта с длительным сроком хранения; при этом рассматриваются научные публикации за период с 2020 по 2026 год.
Ключевые слова: постбиотики; ферментация; инактивация; последующая обработка; биоактивы.

Introduction

Probiotics have for a long time been used in order to support the gut microbiota; yet their use in targeted therapy is limited due to their poor survival in acidic and bile environments (Nataraj et al., 2020; Thorakkattu et al., 2022). Other problems involve the need for special storage conditions and difficulties in standardizing the dose (Thorakkattu et al., 2022). Because of these limitations, there has been growing interest in safer and more stable alternatives. The International Scientific Association of Probiotics and Prebiotics (ISAPP) defines postbiotics as "inanimate microorganisms and/or their

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components that confer a health benefit on the host" (Salminen et al., 2021). As the health benefits of probiotics are mainly achieved through their metabolites, it is not necessary to administer the live cells (Nataraj et al., 2020; Vinderola et al., 2022). Fermentation is still a key process in the manufacture of postbiotics (Mishra et al., 2024). The present review examines each stage of the fermentation-based production process, from strain selection to downstream processing.

Methods

The literature was searched in PubMed, NIH, Elsevier, ScienceDirect and MDPI between 2020 and 2026, with a focus on scientific articles, peer-reviewed studies and consensus statements concerning postbiotic production. The ISAPP consensus documents were included in order to provide a theoretical background.

Results

The strains used include lactic acid bacteria and various *Bifidobacterium* species (Moradi et al., 2020); additionally, *Streptococcus*, *Bacillus*, and yeasts such as *Saccharomyces cerevisiae* are employed in order to obtain postbiotics with a broader range of effects (Nataraj et al., 2020). The pure cultures are introduced into media such as MRS broth, milk proteins, or whey (Trymers et al., 2026).

The type of fermentation used – submerged or solid-state – is determined by the desired postbiotic (Ali-Haneef et al., 2026). In a particular study, solid-state fermentation using *Bacillus amyloliquefaciens* and *Lactiplantibacillus plantarum* yielded a crude preparation that had improved antibacterial properties against *Salmonella* and *E. coli*, together with antioxidant and anti-inflammatory effects (Tong et al., 2023). The incubation is generally carried out at a temperature of 30-37°C for a period of 25 to 48 hours (Liang & Xing, 2023). Complex metabolites such as bacteriocins and exopolysaccharides are primarily produced during the stationary phase, when quorum sensing is active (Bueno et al., 2025).

The inactivation of microorganisms continues to rely on thermal methods, such as pasteurizing at a temperature between 70 and 90°C for a period of 15 to 30 minutes or autoclaving at 121 °C for 15 to 20 minutes (Ali-Haneef et al., 2026). Occasionally, non-thermal techniques – such as high-pressure processing, ultrasonic cavitation, and pulsed electric fields – are preferred in order to prevent damage to heat-sensitive bioactives (Thirumdas & Mudgil, 2025).

Regarding verification, the ISAPP consensus states that manufacturers must show that there are no viable colony-forming units left (Salminen et al., 2021); this is achieved by pouring samples onto selective agar media and then confirming that no growth occurs after incubation (Vinderola et al., 2025).

The downstream processing involves converting the inactivated broth into a standardized and shelf-stable ingredient. By means of centrifugation or ultrafiltration (Prajapati et al., 2023), the cell debris and whole cells are removed, and the resulting clear liquid is then concentrated using low-temperature vacuum evaporation. Since postbiotic extracts are very hygroscopic, carriers like maltodextrin or starch are included in order to protect them from both oxygen and heat; dehydration and stabilization are subsequently carried out by means of spray-drying or freeze-drying (Ren et al., 2026).

Discussion

The main conclusion is that the postbiotic quality is affected at all stages of production—covering the choice of strain and medium, fermentation, inactivation, and downstream processing—and is therefore not determined entirely by the strain.

The form of fermentation has an effect on both the kind and the strength of the product (Ali-Haneef et al., 2026; Tong et al., 2023), and since important metabolites build up during the stationary phase, both the time of harvest and the temperature used have a direct impact on the yield and on the composition (Bueno et al., 2025; Netrusov et al., 2023). Inactivation involves a compromise: thermal methods are simple and reliable but can cause degradation of sensitive bioactives, whereas non-thermal methods maintain bioactivity although at the cost of greater expense and complexity

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(Thirumdas & Mudgil, 2025). Regardless of the method chosen, plating-based verification is an essential step in quality control (Salminen et al., 2021; Vinderola et al., 2025).

It is necessary to recognize a number of limitations. The compositional complexity of postbiotics makes it hard to reproduce and characterize (Scott et al., 2022; Guglielmetti et al., 2025). Moreover, some of the material on manufacturing is written by people from the industry and has not been subject to peer review.

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