

Innovative Solutions in Food Biotechnology: Advancing Sustainable, Resilient, and Health-Oriented Food Systems

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Article Information

Article history:

Received 16 Sep 2025
Revised 4 Nov 2025
Accepted 17 Nov 2025
Published 30 Dec 2025

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To cite: Khosravi-Darani K, Rezaei-Savadkouhi N, Zerafati-Shoae N. *Innovative Solutions in Food Biotechnology: Advancing Sustainable, Resilient, and Health-Oriented Food Systems*. *Appl Food Biotechnol*. 2025; 12 (1): e34.
<http://doi.org/10.22037/afb.v12i1.52439>

Abstract

Global food systems are facing increasing challenges associated with population growth, climate change, environmental pressures, resource limitations, and the demand for safe and nutritious foods. Food biotechnology has emerged as an interdisciplinary field that contributes to addressing these challenges through innovations in microbial processes, bioprocess engineering, food safety technologies, and the development of functional food ingredients. This editorial provides an overview of the research topics presented in this issue of Applied Food Biotechnology. The published articles cover a broad range of subjects, including microbial biotechnology, fermentation technologies, probiotics and postbiotics, enzyme engineering, bioactive compounds, food safety interventions, pathogen control, nanobiotechnology, and sustainable bioprocesses. Several studies examine approaches for improving microbial performance, enhancing food quality, optimizing biotechnological production systems, and increasing the stability and functionality of food ingredients. Other contributions focus on food preservation, antimicrobial strategies, waste valorization, alternative bioresources, and applications relevant to sustainable food production. Collectively, these studies reflect current research directions in food biotechnology and highlight the diversity of biotechnological approaches being explored to support food quality, safety, functionality, and sustainability. The findings presented in this issue may contribute to future developments in research, industry applications, and evidence-based decision-making within the food sector.

Keywords: Food biotechnology, Food safety, Fermentation, Functional foods, Sustainable food production, Bioprocess engineering, Bioactive compounds, Probiotics

1. Introduction

The ever-evolving field of applied food biotechnology is at the forefront of addressing global challenges in food production, safety, and sustainability. The 2025 issue of Applied Food Biotechnology encapsulates significant advancements and novel approaches that enhance our understanding and utilization of biotechnological applications in the food industry. As we delve into this rich body of research, it is essential to reflect on the implications these findings have for the industry as well as for the consumers who depend on the food supply. Importantly, the convergence of biotechnology, sustainability, and health-oriented food innovation is reshaping global food systems and creating new opportunities to address food security and environmental challenges. One prominent area of focus is

the development of novel microbial strains engineered for enhanced flavor profiles and nutritional benefits in fermented foods. Research shows that these strains not only improve organoleptic qualities but also boost the bioavailability of nutrients. This dual benefit is essential in catering to increasingly health-conscious consumers who seek functional foods. There are a few reports related to the use of microbes in food production, including fermentation processes, microbial strains, and their applications in enhancing food products (e.g., biofilm formation, probiotic potential) [1-10]. Collectively, these studies demonstrate the growing importance of microbial biotechnology as a key driver of innovation in modern food systems. Research that focuses on biotechnological methods employed in food production, such as enzyme engineering, optimization of

fermentation processes, and the use of nanotechnology nanotechnology has highlighted the potential of advanced bioprocesses to improve productivity, product quality, and sustainability throughout the food value chain [11-15].

Articles examining the health benefits, bioavailability, and characterization of bioactive compounds from food sources (e.g., selenium-enriched microalgae, CLA production in lactic acid bacteria) [16-20]. These findings support the increasing demand for functional foods capable of delivering health benefits beyond basic nutrition.

Food safety remains a paramount concern, and the studies in this issue provide valuable insights into biotechnology's role in mitigating risks associated with foodborne pathogens. Innovative approaches in biosensors and rapid detection methods have emerged from applied research, enabling quicker responses to contamination events. These technologies are crucial for maintaining consumer trust and ensuring public health. Research address food safety, pathogen control, and quality improvement through microbiological intervention or other means (e.g., biocontrol strategies, antimicrobial properties of various treatments) [10, 21-25]. Moreover, exploring methods for the preservation of food products using natural biopreservatives derived from microbial sources reinforces the trend towards clean-label products. Such biotechnological enhancements not only extend shelf life but also align with consumer preferences for minimally processed foods. Together, these developments contribute to safer and more transparent food production systems.

Sustainability is a central theme throughout the issue, with a special focus on bioprocesses that minimize waste and utilize by-products efficiently. The shift towards circular economy principles in food production is gaining momentum, whereby waste from one process serves as a resource for another. The research showcased reinforces the feasibility of integrating biotechnological innovations in reducing the overall environmental footprint of food production systems. Studies involving novel food processing techniques, including optimization of media for microbial growth or novel extraction methods (e.g., steam distillation, deproteinization processes). [3, 12-15, 21-25]. These advances are particularly relevant in the context of climate change, resource scarcity, and global efforts to establish more sustainable food production systems.

A few researchers focused on developing functional foods enriched with specific health-promoting components, understanding their effects on health, and evaluating their sensory attributes (e.g., nutritional coffee with probiotics). [2, 5-10, 20, 22-25]. In probiotics and fermented food, we had a paper about the era of plant-based probiotics, and survival of bacterial population kinetics and physicochemical profiles in a fermented goat milks and lactic acid bacterial community of Dhan. Also, study on the

acetaldehyde and diacetyl producing abilities of enterococcus and lactobacillus strains isolated from yogurt were reported. Many other aspects of probiotic studies from survival and cell count to sensory evaluations and postbiotics [2, 5-10, 20, 22-23]. Taken together, these studies strengthen the scientific basis for the development of next-generation probiotic and functional food products.

Enzymatic engineering and nutritional enhancement were considered in engineered phytase for improved thermostability and catalytic efficiency: Impacts on nutrient bioavailability. Tabasi et al. reported improved production of food-grade hyaluronic acid in recombinant *Corynebacterium glutamicum*. Also, Optimization of culture media parameters of *Saccharomyces cerevisiae* for maximized invertase enzyme production. Functional characterization of a novel heat-stable recombinant bacteriocin was also reported [11, 13-15, 25]. These studies illustrate how biotechnology can simultaneously improve nutritional quality, industrial efficiency, and commercial scalability. Additional contributions included the investigation of cytotoxic peptides derived from *Chlorella vulgaris* proteins [26], deproteinization of shrimp shell chitin and nanochitin characterization [27], development of laccase-based biosensors for phenolic acid determination [28], trilayer nanofiber systems for enhancing probiotic survival [29], computational design of sustainable milk-clotting peptides [30], production of *Rosa damascena* nanoemulsions with improved antibacterial activity [31], and assessment of amino acid composition in traditional Shubat dairy products [32]. These studies further expand the scope of food biotechnology from functional ingredients and biosensors to sustainable processing technologies and novel food products.

Earlier studies in food biotechnology have also provided a strong scientific foundation for many of the innovations highlighted in this issue. The development of kombucha microbial starters with enhanced antioxidant production and invertase activity demonstrated the potential of fermentation biotechnology to create value-added functional beverages with improved health-promoting properties [33]. Similarly, the utilization of sugar refinery waste for the production of biodegradable polyhydroxybutyrate (PHB) emphasized the role of industrial biotechnology in supporting sustainable food-packaging solutions and circular bioeconomy principles [34]. Natural antimicrobial systems have also attracted considerable attention in food preservation. Encapsulation of *Zataria multiflora* essential oil in liposomal structures significantly improved its antibacterial efficacy against foodborne pathogens, providing an alternative to synthetic preservatives [35]. In addition, the bioconversion of agricultural and food-processing residues into high-value mycoprotein through fungal fermentation demonstrated a sustainable approach to alternative protein



production while reducing environmental burdens associated with food waste [36]. Food safety and quality enhancement have likewise benefited from biotechnological innovations. The application of probiotic bacteria for patulin removal from synbiotic apple juice illustrated an effective strategy for mitigating mycotoxin contamination and improving consumer safety [37]. Furthermore, research on supercritical fluid science highlighted the versatility of environmentally friendly extraction and processing technologies for the recovery of valuable bioactive compounds and the development of advanced food products [38]. Collectively, these pioneering studies have contributed substantially to the evolution of sustainable, safe, and health-oriented food biotechnology and continue to inspire emerging research directions in the field [33–38].

2. Conclusion

The contributions made in this issue of Applied Food Biotechnology signify a pivotal moment in our approach to food system challenges. By embracing biotechnological innovations while keeping sustainability and safety at the forefront, we can build a resilient food future. As we move forward, continued research, dialogue, and collaboration will be essential in harnessing the full potential of biotechnology for the betterment of society. As we look to the future, it is clear that the interplay between biotechnology and food systems will only deepen. There is a pressing need for collaborative efforts among researchers, industry stakeholders, and policymakers to create frameworks that support innovation while ensuring safety and ethical considerations are met. Addressing regulatory challenges and public perception will be vital for the successful adoption of these advanced biotechnologies. The following topics reflect the ongoing challenges and innovations in the field of food biotechnology and may shape the research landscape in journals like Applied Food Biotechnology in next years: studies exploring the role of beneficial microorganisms in food products, the development of new fermentation techniques, and their impact on flavor, nutrition, and health benefits; application of genomic and metagenomic technologies to understand microbial communities in food systems and enhance food quality and safety; exploration of biotechnological methods to support regenerative agriculture, which enhances soil health and biodiversity while improving food security; studies examining consumer attitudes toward biotechnologically derived foods, the influence of labeling, and the ethical considerations surrounding food biotechnology.

The application of CRISPR technology in crop modification may address significant agricultural challenges, allowing for the creation of more resilient food sources. By minimizing susceptibility to pests and

environmental stressors, we can ensure a more stable food supply, which is especially critical in the face of climate change.

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راهکارهای نوآورانه در بیوتکنولوژی مواد غذایی: پیشبرد سیستم‌های غذایی پایدار، تاب‌آور و سلامت‌محور

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تاریخچه مقاله

دریافت ۱۶ سپتامبر ۲۰۲۵
داوری ۴ نوامبر ۲۰۲۵
پذیرش ۱۷ نوامبر ۲۰۲۵
چاپ ۳۰ دسامبر ۲۰۲۵

نویسنده مسئول

کیانوش خسروی دارانی

تلفن: ۰۲۱-۲۲۰۸۶۳۴۸

فاکس: ۰۲۱-۲۲۳۷۶۴۷۳

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چکیده

سامانه‌های غذایی جهان با چالش‌های فزاینده‌ای از جمله رشد جمعیت، تغییرات اقلیمی، فشارهای زیست‌محیطی، محدودیت منابع و افزایش تقاضا برای غذاهای ایمن و مغذی روبه‌رو هستند. زیست‌فناوری غذایی به‌عنوان یک حوزه میان‌رشته‌ای، از طریق نوآوری در فرایندهای میکروبی، مهندسی زیست‌فرایندها، فناوری‌های ایمنی غذا و توسعه ترکیبات عملکردی، در پاسخ به این چالش‌ها نقش مهمی ایفا می‌کند. این سرمقاله مروری بر موضوعات پژوهشی منتشرشده در این شماره از Applied Food Biotechnology ارائه می‌دهد. مقالات این شماره طیف گسترده‌ای از موضوعات شامل زیست‌فناوری میکروبی، فناوری‌های تخمیر، پروبیوتیک‌ها و پست‌بیوتیک‌ها، مهندسی آنزیم، ترکیبات زیست‌فعال، راهکارهای ایمنی غذا، کنترل پاتوژن‌ها، نانوزیست‌فناوری و زیست‌فرایندهای پایدار را پوشش می‌دهند. تعدادی از مطالعات بر بهبود عملکرد میکروارگانیسم‌ها، ارتقای کیفیت غذا، بهینه‌سازی سامانه‌های تولید زیستی و افزایش پایداری و کارایی ترکیبات غذایی تمرکز دارند. برخی دیگر به نگهداری مواد غذایی، راهبردهای ضد میکروبی، ارزش‌افزایی پسماندها، بهره‌برداری از منابع زیستی جایگزین و کاربردهای مرتبط با تولید پایدار غذا می‌پردازند. در مجموع، این مطالعات بازتاب‌دهنده روندهای جاری پژوهش در حوزه زیست‌فناوری غذایی بوده و تنوع رویکردهای زیست‌فناورانه مورد بررسی برای حمایت از کیفیت، ایمنی، عملکرد و پایداری سامانه‌های غذایی را نشان می‌دهند. یافته‌های ارائه‌شده در این شماره می‌توانند در توسعه تحقیقات آینده، کاربردهای صنعتی و تصمیم‌گیری مبتنی بر شواهد در بخش غذا مؤثر باشند.

واژگان کلیدی: زیست‌فناوری غذایی، ایمنی غذا، تخمیر، غذاهای عملکردی، تولید پایدار غذا، مهندسی زیست‌فرایند، ترکیبات زیست‌فعال، پروبیوتیک‌ها