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Footprints of Biotechnology in the Food Industry

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The elucidation of DNA structure in 1953, by Watson and Crick using the crystallographic work of Rosalind Franklin, make a watershed on biological sciences, especially in biotechnological area, building the scaffold to the modern biotechnology. This multidisciplinary science has emerged as a transformative force in the food industry, revolutionizing traditional practices and enabling innovative solutions to global challenges such as food security, sustainability, and nutrition. In the next paragraphs, it will be explored the multifaceted impact of biotechnology on food development, quality enhancement, safety assurance, and sustainability, and highlight the potential of biotechnological advancements to reshape food production and processing.

The global food industry faces unprecedented challenges, including population growth, climate change, resource scarcity, and evolving consumer demands (Mohammad et. al., 2024). Biotechnology offers tools to address these issues by enhancing food production, improving nutritional profiles, and ensuring safety. Biotechnology is defined as the application of biological systems and organisms to develop or modify products and processes, and has found extensive applications in agriculture, food processing, and quality control (Kumar & Kaur, 2022). Although biotechnology has been associated with transgenics and genetically-modified organisms (GMO´s), it has ethical controversial applications. The impact of biotechnology in the transformation of the food industry has represented positive benefits, and it is necessary to consider its limitations and future perspectives, topics that will be covered during this short writing.

Biotechnology has enabled the development of novel food products through genetic modification and microbial engineering. Genetically modified organisms (GMOs) such as golden rice enriched with vitamin A and drought-

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resistant maize have improved food availability and nutritional value (Wadvalla, 2022). Microbial biotechnology, using genetic engineering to improve metabolic pathways, has facilitated the production of alternative proteins and bioactive compounds from fungi, algae, and bacteria, offering sustainable options to traditional animal-based proteins (Fleming, 2025). An important facet of food innovations is the use of food by-products to improve the circular economy and sustainability to address food security and environmental concerns while catering to changing dietary preferences. From food by-products can be extracted compounds with different biological activities, such as antioxidant activity, texturizers, sweeteners, acidifiers, and antimicrobials, among others. These compounds are added to enhance the nutritional and sensorial quality of foods and provide healthy food options to consumers (Nirmal et al., 2023).

Biotechnological research has influenced the improvement of the sensory and nutritional quality of foods. Fermentation using genetically engineered or selected microbes enhances the flavor, texture, and shelf life of products like cheese, yogurt, and bread (Li et al., 2025). An example of these selected microbes is the probiotics, beneficial microorganisms that, in addition to their well-known health benefits, improve the organoleptic characteristics of the foods that contain them. A relatively recent concept is symbiotic foods, where a previously identified and characterized probiotic microorganism is combined with prebiotics, generally carbohydrates only digested by probiotics, to enhance the functional and nutritional characteristics of food (Peng et al., 2020).

The enhancement can be done since the crops for food production are cultured, biofortification techniques increase the concentration of essential micronutrients, for instance, iron-enriched beans and zinc-fortified wheat are outcomes of targeted genetic modifications. On the other hand, the ancestral use of sourdough in bakery has gained importance due to the use of microbial consortia that produce flavor and textures, creating novel and pleasant sensory experiences to the consumer and also improving the nutritional facts of the bread (Poutanen et al., 2009). These advancements contribute to healthier diets and improved public health outcomes.

Ensuring food safety is a critical aspect of biotechnology applications. Molecular diagnostics, such as PCR and biosensors, detect pathogens, toxins, and contaminants with high sensitivity and specificity, and better yet, decrease the time-consuming and human resources (TeselaGen, 2023). Microorganisms produce secondary metabolites during their growth; many of those metabolites, like bacteriocins, can be exploited for biopreservation, and the expansion of harmless microbes over foods acts as protective cultures inhibiting spoilage organisms and extends shelf life (Ding & Song, 2025).

A growing area in food industrial manufacturing is the detection of fraudulent foods. Here, a novel tool based on detecting the DNA present in the raw material of food can be employed to discriminate between species (Galimberti et. al, 2013). This tool is based on detecting a highly evolved DNA fragment under 1000 bp at 5´ end of the barcoding gene, which, depending on species, is localized in the genome, chloroplasts, or mitochondria. DNA barcoding and blockchain-integrated traceability systems enhance transparency and consumer trust in food supply chains. These technologies mitigate risks and support regulatory compliance.

Despite its benefits, biotechnology in food raises ethical and social concerns. Public apprehension about GMOs, labeling transparency, and potential ecological impacts necessitate robust regulatory frameworks. Ethical debates center around gene editing, animal welfare, and equitable access to biotechnological innovations. Regulatory bodies such as the FDA, EFSA, and WHO play pivotal roles in evaluating safety and guiding policy. Addressing these challenges requires stakeholder engagement, risk communication, and interdisciplinary collaboration.

The future of food biotechnology lies in precision breeding, synthetic biology, and digital integration. CRISPR-Cas9 technology offers targeted gene editing with minimal off-target effects, enabling the creation of customized crops and microbes. Artificial intelligence and machine learning enhance bioprocess optimization and predictive modeling. As consumer demand for sustainable and functional foods grows, biotechnology will continue to drive innovation. However, ethical governance and public acceptance will determine its trajectory.

Biotechnology has significantly influenced the transformation of the food industry by enabling the development of novel products, enhancing quality, ensuring safety, and promoting sustainability. While the potential is vast, responsible implementation guided by ethical principles and regulatory oversight is essential. Continued research, education, and dialogue among stakeholders will facilitate the integration of biotechnology into mainstream food systems, addressing global challenges and improving human well-being.

References

Bhat, M.M., Bashir, Z., Hamid, B., & Nisa, M. (2025). Impact of the synthetic fertilizer pesticides on soil health and soil microbiology. In *Organic Farming* (pp. 282-302). CRC Press.

Fleming N. (2025). Could these five future agricultural innovations slow down climate change? Nature, Advance online publication. DOI: 10.1038/d41586-025-02321-3.

Galimberti, A., De Mattia, F., Losa, A., Bruni, I., Federici, S., et. al. (2013). DNA barcoding as a new tool for food traceability. *Food research international*, 50(1), 55-63.

Kumar, A., & Kaur, R. (2022). Recent trends in food biotechnology contributing in food production and processing. In A. Kumar & R. Kaur (Eds.), *Recent Advances in Food Biotechnology* (pp. 3–14). Springer. DOI: 10.1007/978-981-16-8125-7_1.

Li, J., Liu, S., Song, H., & Ding, S. (2025). Microbe discovery holds promise for sustainable biotechnology. *Nature*, 646(8084), 288. DOI: 10.1038/d41586-025-03278-z.

Mohammad, Z. H., Ahmad, F., & Ibrahim, S. A. (2024). Biotechnology approaches to food security: risks and solutions. In F. Ahmad et al. (Eds.), *Microbial Biotechnology in the Food Industry* (pp. 1–13). Springer. DOI: 10.1007/978-3-031-51417-3_1.

Nirmal, N.P., Khanashyam, A.C., Mundanat, A.S., Shah, K., Babu, K.S., et. al. (2023). Valorization of fruit waste for bioactive compounds and their applications in the food industry. *Foods*, *12*(3), 1–26. DOI: 10.3390/foods12030556.

Peng, M., Tabashsum, Z., Anderson, M., Truong, A., Houser, A.K., et. al. (2020). Effectiveness of probiotics, prebiotics, and prebiotic-like components in common functional foods. Comprehensive reviews in food science and food safety, 19(4), 1908-1933. DOI: 10.1111/1541-4337.12565.

Poutanen, K., Flander, L., & Katina, K. (2009). Sourdough and cereal fermentation in a nutritional perspective. *Food Microbiology*, *26*(7), 693–699. DOI: 10.1016/j.fm.2009.07.011.

TeselaGen. (2023). Solving biotech challenges with AI. Nature. https://www.nature.com/articles/d43747-023-00027-x.

Wadvalla, B.-A. (2022). Advancing biotechnology to solve Africa's food challenges. Nature. https://www.nature.com/articles/d44148-022-00106-8.