

Title: A Comprehensive Review of Biotechnological Innovations in Valorization of Food Waste: Enhancing Nutritional, Techno-Functional Properties, and Process Optimization for Sustainable Product Development

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Abstract: Biotechnological valorization of food waste into functional ingredients emerges as an attractive green solution, feasible for the food production chain worldwide. A variety of key technologies, including microbial fermentation, enzyme hydrolysis, and membrane filtration, can be employed to develop bioactive compounds with supplemented nutrition and techno-functional features from food waste. In the present review, progress in the valorization of several types of food-waste streams, including fruit peels, spent grain, dairy whey, grape pomace, vegetable by-products, and seafood residue, has been discussed in depth. In addition, many benefits resulting from food products or semi-finished foods and beverages, including enhanced bioavailability, antioxidant activity, improved nutritional value, and extended shelf life, may be achieved using biotechnological approaches, predominantly these novel bioactive ingredients. Furthermore, numerous process optimization techniques, like kinetic modeling, response surface methodology (RSM), and techno-economic assessment, have been adopted to enhance bioproduction, cost, and scale-up. Finally, successful commercial case reports demonstrate the usefulness of using these food-waste-derived ingredients in the creation of functional foods, nutraceuticals, and active packaging. In any case, large-scale generation, along with regulatory approval requirements and consumer acceptance, limit the widespread adoption of this technology. Therefore, the ultimate objective of the review is to characterize the current situation and propose potential research that would aid the establishment of sustainable and circular food regions through novel waste valorization. Additionally, governments and industry should establish guidelines and incentives to ensure that food production using these technologies remains both environmentally and economically sustainable.

Keywords: bioactive compounds , food waste , functional ingredients , process optimization , resilient food system , sustainable bioprocessing

<https://doi.org/10.1002/fft2.70194> Digital Object Identifier (DOI)

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