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Agri-Pharma-Food Nexus: Harnessing Edible Plants as Bio-factories for Next-Gen Pharmaceuticals

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Abstract

The intersection of agriculture, pharmaceutical innovation, and food science is giving rise to a transformative field: the use of edible plants as platforms for pharmaceutical production, commonly referred to as molecular pharming. This review explores the current advances, opportunities, and challenges associated with utilizing genetically engineered crops—such as lettuce, rice, maize, and tomatoes—to produce therapeutic proteins, vaccines, and antibodies. Compared to traditional bioreactor-based methods, plant-based expression systems can reduce production costs by up to 60% and lower the risk of contamination by approximately 80%. Key developments in chloroplast transformation, transient expression systems, and glycoengineering have improved protein yields to levels of 1.5–3.0% of total soluble protein in edible tissues. The review highlights successful case studies, including plant-derived vaccines for hepatitis B and Norovirus, which showed immunogenic responses in 75–90% of subjects during early trials. In addition to cost-effectiveness and scalability, these edible plant platforms offer the potential for oral delivery, eliminating the need for cold-chain logistics and sterile injection, which could increase global vaccine accessibility by over 40%. Critical discussions include the regulatory landscape, biosafety, and consumer perception—particularly concerning genetically modified organisms (GMOs) in the food chain. This review emphasizes that with standardized protocols and robust safety evaluations, molecular pharming can play a pivotal role in decentralizing pharmaceutical production, particularly in low- and middle-income regions.

Keywords: Molecular pharming, plant-made pharmaceuticals, edible vaccines, agri-pharma integration, sustainable bioproduction.