

## **Development of innovative products based on prickly pear cactus (*Opuntia* spp.): biochemical potential, technological advances, and sustainability perspectives**

### **Abstract**

The prickly pear cactus (*Opuntia* spp.) is emerging as a strategic resource for sustainable innovation in the agri-food and nutraceutical sectors. Rich in bioactive compounds, including polyphenols, flavonoids, betalains, dietary fibers, and essential minerals, *Opuntia* exhibits antioxidant, anti-inflammatory, hypoglycemic, and anti-obesogenic properties. These features underpin its classification as a functional food and make it a promising ingredient for novel product development. This review explores recent advances in the biochemical characterization, processing technologies, and application of prickly pear derivatives (cladodes, fruits, peels, seeds, and mucilage) in functional foods such as jellies, beverages, flours, probiotic and postbiotic formulations. Furthermore, in vitro propagation techniques and sustainable cultivation practices (e.g., micropropagation with cost-effective nutrient media and circular bioeconomy models) are discussed as viable pathways to enhance large-scale production and ensure resilience in semi-arid regions. Drawing on recent studies and the latest research, this review also addresses social, economic, and environmental drivers of innovation adoption among smallholder farmers. By bridging gaps between agronomic potential, food technology, and circular economy principles, the valorization of prickly pear cactus can contribute to climate-adapted agriculture, food security, and the UN Sustainable Development Goals. The integration of biotechnological, ecological, and socio-economic dimensions is critical to unlocking the full potential of this underutilized crop.

**Keywords** - prickly pear, functional foods, bioactive compounds, food innovation, sustainable agriculture