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Editorial: Sustainable active packaging for food safety and preservation: technological, consumer, and environmental perspectives

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Editorial on the Research Topic
Sustainable active packaging for food safety and preservation: technological, consumer, and environmental perspectives

Introduction

Growing concerns about the environmental impact of petroleum-based plastics, along with consumer demand for sustainable solutions that also ensure food safety and quality, have driven the development of biodegradable active packaging. These eco-friendly alternatives go beyond the basic role of packaging by including functional agents, such as antioxidants, antimicrobials, ethylene scavengers, or modified atmospheres, that help preserve food quality and extend shelf life.

To develop such packaging, researchers are investigating a wide range of biopolymers derived from plant, animal, or microbial sources, either individually or in combination. These efforts have led to innovative advances in the field. However, despite the progress, significant challenges remain. A primary concern is replicating the mechanical strength, appearance, and protective qualities of traditional plastics, while maintaining sensory properties. Additional barriers include the difficulty of scaling production and the high cost associated with biopolymer materials.

To address these issues, several strategies are being explored. These include reinforcing biopolymers with nanomaterials to enhance their mechanical and barrier performance, blending synthetic and natural polymers, incorporating bioactive compounds to improve shelf life, and applying emerging processing technologies that are compatible with biopolymers. Optimizing existing processes to reduce environmental impacts is also an important focus.

This Research Topic brings together original research that contributes to overcoming these challenges. The articles present fill key knowledge gaps and introduce new approaches to active packaging. The goal is to offer a broad view of how packaging innovation can meet the food industry's evolving needs while supporting environmental goals.

Key findings

This Research Topic comprises six contributions, including five original research articles and one mini-review, collectively providing a comprehensive overview of sustainable active packaging for food safety and preservation. The presented studies investigate various innovations, from low-tech storage solutions to sophisticated bio-based coatings, thereby exemplifying the interdisciplinary nature of this expanding field. Each contribution offers insights into technological, consumer, or environmental aspects of packaging, with an emphasis on enhancing food quality, minimizing waste, and advancing circular economy principles.

The first article by Swathi et al. evaluates triple-layer high-density polyethylene (HDPE)/polypropylene (PP) hermetic storage bags to protect groundnut pods from *Caryedon serratus* and *Aspergillus flavus* damage under two moisture levels (10% and 14%). These bags were compared with PP, jute and jute with a natural insecticide as more traditional alternatives over a 6-month storage period. The multilayer HDPE/PP bags completely prevented insect infestation, with no egg-laying, pupation, adult emergence, pod damage, or weight loss observed. Even though HDPE and PP are plastics derived from fossil fuels, they are recyclable, specially HDPE. Their sustainability depends mainly on factors like production methods and end-of-life management. The following contributions will focus on bio-based alternatives to traditional synthetic polymers.

In the second contribution, Mohammed et al. optimize an innovative ultrasonic coating system using gum Arabic to extend the shelf life and preserve the quality of fresh date palm fruits. By applying response surface methodology, the researchers identified optimal coating and storage conditions that extended fruit shelf life up to 60 days with minimal ripening, color change, and weight loss. The ultrasonic technique ensured a uniform coating, proving to be an effective and innovative method for preserving fresh dates.

The third contribution by Kaur et al. follows a similar approach to that of Mohammed et al. In this case, authors studied the effectiveness of combined Aloe vera (AV) and chitosan (CH)-based edible coatings in extending the shelf life and preserving the quality of fresh fig fruits. Among several treatments, the combination of 50% AV and 1% CH (25:75) significantly reduced decay, microbial load, and nutrient loss, extending shelf life up to 21 days under cold storage. Combined AV and CH proved to be more efficient than individual coatings, offering a promising, scalable sustainable solution for fig preservation.

The study by Marcovich and Ansorena, the fourth contribution, investigates bio-based gelatin/chitosan films infused with thyme essential oil (TEO), available in both free and microencapsulated forms, as eco-friendly coatings for fresh-cut kiwi. Microencapsulated TEO in β-cyclodextrin demonstrated to enhance mechanical strength, barrier, and antimicrobial features of films, effectively reducing weight loss, microbial contamination, and maintaining antioxidant activity in kiwi fruits over 12 days of cold storage. Furthermore, kiwis coated with these films retained high sensory appeal, emphasizing the potential of this sustainable packaging to extend shelf life and promote food safety in minimally processed fruits.

The fifth study, by Malbos et al., explores the impact of both accelerated and natural weathering on plasticized polylactic acid (PLA) films and PLA blended with thermoplastic starch (TPS). Their findings reveal that PLA/TPS blends degrade rapidly, within just 24 h under accelerated conditions, whereas pure PLA films show a gradual increase in crystallinity, reduced transparency, and a decline in mechanical strength over time. Similar trends were observed in outdoor exposure tests conducted over longer durations. These results support the use of PLA/TPS blends as cost-effective, biodegradable materials suitable for single-use packaging, offering improved environmental performance.

In their mini-review, Wardana et al. examine the potential of Pickering emulsions stabilized by cellulose nanomaterials (CNMs) as sustainable edible coatings for postharvest fruit preservation. CNMs enhance the stability, barrier function, and antimicrobial properties of these coatings by forming dense interfacial layers and regulating the release of active compounds. Such coatings can effectively delay ripening and inhibit microbial spoilage. The authors concluded that future efforts should focus on refining coating formulations for large-scale application and systematically evaluating their sensory impact, thereby supporting their broader implementation in fruit preservation and logistics.

Together, the articles in this Research Topic reflect the evolving landscape of sustainable food packaging technologies. From traditional recyclable packaging to the potential of natural polymers and blends, this Research Topic shows microencapsulated bioactive compounds, innovative coating systems and composite biodegradable materials to improve food safety and shelf life while minimizing environmental impact. These findings contribute valuable knowledge to the development of packaging systems that are not only effective and scalable but also aligned with global sustainability goals. We hope this Research Topic inspires further interdisciplinary research and innovation in active and intelligent packaging solutions for a safer and more sustainable food system.

Author contributions

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