coatings

Editorial
Recent Trends in Antibacterial Coatings and Biofilm

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In modern society, the growing use of plastic packaging has innumerable and unquestionable consequences. Even though this type of packaging plays an essential role in the global economy and presents numerous advantages, it also has several disadvantages, especially regarding environmental pollution. As conventional/synthetic materials account for over 50% of the materials used for packaging in the food industry, it is crucial to produce eco-friendly, active/edible, and intelligent packaging with antimicrobial properties [1,2]. Another essential aspect of the adoption of biodegradable, eco-friendly packaging is the reduction in greenhouse gas emissions and the transition from a "linear economy" (where the use of fossil fuels and unrecyclable materials is prevalent) to a "circular economy" (no/or minimal waste, by-product reutilization) [3]. This transition requires a reassessment of plastic's life cycle from its base materials to production and recirculation [4,5].

The most important aspect of food packaging is maintaining foodstuffs' appearance and quality, thereby significantly increasing perishable commodity foods' shelf life [6]. Foodborne pathogenic microorganisms are responsible for several diseases worldwide, with the most widely known being *Salmonella* spp., *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Listeria monocytogenes*, and *Escherichia coli*. Bio-based biodegradable materials can successfully be used as a substitute for non-renewable fossil-based polymers by integrating antimicrobial compounds. These can be organic materials, such as enzymes, proteins, and polymers, or bioactive compounds extracted from food by-products. The integration of bioactive compounds (i.e., macronutrients, phytochemicals) in these eco-friendly materials can confer antimicrobial and antioxidant properties and improve the biofilm's physical–chemical properties [7–10]. As a consequence, productive packaging is vital to protect food from the surrounding environment throughout transportation, storage, and distribution [11].

Increased attention is given to the production of polysaccharide-based edible materials such as alginate, pectin, chitosan, carrageenan, cellulose, xanthan, and other polymers. These materials have gained particular interest in the last few years as a consequence of being natural, regenerable, and abundant [12,13]. Nevertheless, synthetic materials, such as polyvinyl alcohol (PVA) and polylactic acid (PLA), are intensively studied in the production of marketable food packaging materials [14,15]. The integration of bioactive molecules, including carotenoids, vitamins, polyphenols, essential oils, and other compounds, especially those loaded in nanocarriers, is vital to conferring these natural or synthetic materials' antibacterial and antifungal qualities [14,16]. Subsequently, these intelligent/active packaging materials diminish lipid oxidation, prevent the growth of microorganisms, can preserve quality, and increase the shelf life of food products.

In addition to natural bioactive compounds, inorganic antimicrobial compounds comprising metal or metal oxide nanoparticles, such as silver or hydroxyapatite or other metal oxides, have been intensively studied, with outstanding results [14,17,18]. Silver nanoparticles can be integrated in TiO_2 and SiO_2 translucent matrices with the help of high-power impulse magnetron sputtering and radio frequency, and display efficient antimicrobial properties against *E. coli* [17]. Antibacterial TiO_2 was also applied to produce a titania-polyurea coating that presented efficient activity against *P. aeruginosa.* Besides using these biopolymers in food packaging, they can also be applied as antimicrobial coatings in sectors such as the medical field, pharmaceutics, electronics, and the cosmetics industry [17–20]. Recently, several studies incorporated antibacterial substances in biopolymers, for instance, fluoroquinolone antibiotics; these can also be efficiently used in the medical field [20,21]. Copper–silver alloy coatings can also be used effectively on door handles or other surfaces as they inhibit the growth of *S. aureus*, *P.aeruginosa*, *E. coli*, and *Enterobacter aerogenes* [22].

Another relevant aspect in producing these antibacterial coatings and films is the integration of various sensors that can distinguish deficiencies through packaging, supervise the food's quality, and specify the freshness of a product [23]. Furthermore, the sensory characteristics should be considered, as several antimicrobial agents confer an unacceptable odor on food products. Additionally, conventional preservation methods negatively affect the nutritional quality of foods. Thus, the shift from synthetic antimicrobials to natural ones is inevitable [24]. To adopt and efficiently commercialize intelligent/active/smart packaging, further research is necessary to find appropriate materials that maintain their distinct features throughout handling, transportation, and storage. Thereby, attention should be given to the technological features, the interaction of the food with the packaging material, sensorial qualities, and cost reduction.

Conflicts of Interest: The authors declare no conflict of interest.

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