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Resurfacing and modernization of edible packaging material technology

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The centuries old practice of edible packaging is resurfacing, but in new forms with new classes of materials, providing functions beyond reduction in waste generation and traditional conservation and increase shelf-life. In this review, we discuss how this ancient tradition is being re-invented in the context of emerging materiomic approaches, which is a tool to design of the edible coatings and films with different functionalities. The discussion includes, but is not limited to, materials used, structure–function relationship, and application of advanced bio-nanotechnology methods in producing edible packaging film and packaging.

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Introduction

Concerns with the negative impact of traditional food packaging materials on the environmental and the need to reduce loss of fresh food through degradation is driving the quest for alternative to conventional packaging materials and formats; primarily plastics, metals, paper, or glass laminates [1••,2]. One such alternative is the use of packaging that are made from edible materials from food grade or underutilized food ingredients [3,4]. Edible packaging is an ancient old technology for food preservation, which is linked to the invention of sausage making, practiced by ancient Sumerians in Mesopotamia, modern-day Iraq at around 3000 BC, and then later in China around 580 BC [5–7]. It was originally a method to preserve meats by stuffing meat pieces into intestines. Since the early 20th century, edible coatings have found application in preventing water loss, and adding shine to fruits and vegetables [8].

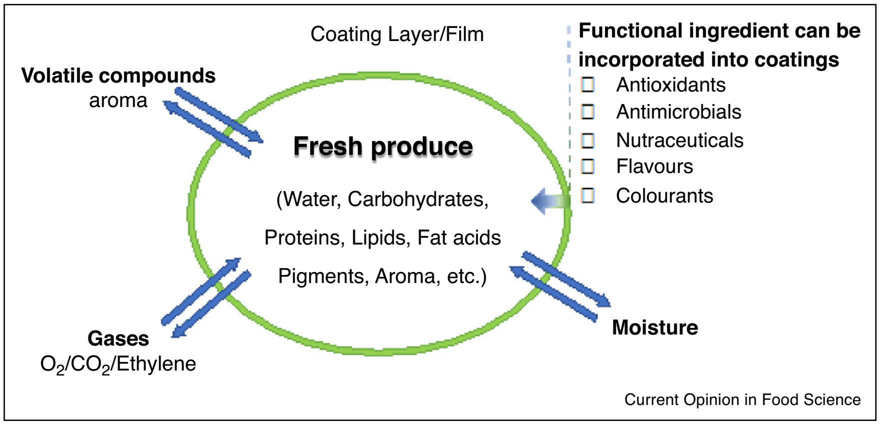
Advancement in the development of edible food coatings slowed down in the 21st century, partly due to cheaply manufactured packaging, which are mostly fossil fuel derived plastics (i.e., from naphtha or natural gas) [9,10••,11,12•]. As awareness of the shortcomings of these traditional food-packaging materials has grown in recent years, the need for edible packaging has resurfaced [1••,13••]. However, the development in these resurfacing food packaging are mostly at the research level, with very limited commercial production and application. Most ongoing research focus on developing food-grade bio-polymeric materials, capable of maintaining or enhancing shelf-life and safety of perishable food products, at nominal packaging costs [11,12•]. The research is also benefiting greatly from advances from other science fields, especially materiomics and nanotechnology.

Materiomics is an emerging field of science focusing on understanding material properties by examining fundamental links between processes, structures, and properties at multiple scales, from nano to macro [14••]. Dealing with materials at nanoscale impacts several stages in the development of edible packaging technology, from principles and synthesis, to functionality of edible films and coating [15•,16]. Thus, this review examines the role of materiomic and nanotechnology in modernizing edible packaging technology. In the process, definitions and principles of edible material as well as an overview of the different categories of edible films and coatings, based on their unique physical–chemical characteristics and film-forming abilities are discussed.

History of edible packaging

The use of edible packaging in the form of coatings and films have reached intensive and complex synthesized biomaterials from humble beginnings [17,18]. From the use of wax to delay dehydration of citrus fruits, and edible coatings to prevent meat shrinkage to a series of discoveries and inventions which have led to a multitude of edible synthetic polymer packaging biomaterials that are used as barriers to both oxygen and aroma compounds and, also serve a functional purpose. Furthermore, there is a growing number of edible polysaccharide coatings, including alginates, carrageenan, cellulose ethers, pectin,

Figure 1



Functional properties of an edible film or coating on fresh food products like meat, fruits, and vegetables.
Source: Modified from Lin and Zhao [3].

and starch derivatives, currently being used to improve stored meat quality [3,6].

Principles of edible packaging

The requirements of edible films and coatings depend on their application and the properties of the food that is to be protected. Currently, most edible films and coatings are mainly applied as a barrier, carrier, or enhancer (Figure 1) [19,20]. As a barrier, the films or coatings protect the food product from exposure to conditions favoring degradation process and against pathogenic microbial contaminants, similar to natural built-in packaging protection like skins and shells on fruit and nuts [4,8,21]. These natural barriers regulate the transport of oxygen, carbon dioxide, and moisture and also reduce flavor and aroma loss [22].

As a carrier, the material for making edible films and coatings can be blended with active compounds like antioxidants, antimicrobial agents, flavoring, pigments, and nutrients (Table 1), either released into the food to slow fouling or reduce contamination, improve or maintain the food's natural appearance and nutritional value. Edible coatings are also made to enhance the mechanical properties of some fragile food products. For instance, chitosan coatings have been used to reduce mechanical damages on strawberries. Furthermore, they may also enhance the appearance and flavor, like use of wax on some fruits (e.g., lemons, oranges, apples), making them appear glossy, while possibly reducing wilting (Table 2).

Edible films and coatings have at least two groups of components: (a) matrix, a biomacromolecule-based cohesive structured biopolymer; and (b) additives like plasticizers, cross-linkers, and nano-reinforcements. Proteins, polysaccharides, lipids, and resins — extracted from plants (e.g., starch, pectin, and cellulose), animals (e.g., collagen, gelatin, and chitosan), microorganisms (e.g., bacterial cellulose), and algae (e.g., alginate and carrageenan) — are commonly used either independently or in combination as precursors to make biopolymers. The polymer matrices are formed through the cross-linking of adjacent chains of the macromolecule by mostly covalent bonds [3,18]. Many other compounds like formaldehyde and glutaraldehyde can induce crosslinking of polymer chains, but most are non-food grade and sometimes, even toxic.

Plasticizers are often required to reduce the brittleness inherent in most biopolymers. They do not chemically bind to the backbone chain but position themselves between the polymer molecules to reduce polymer chain-to-chain interaction. The most commonly used plasticizer is glycerol. Others include low-molecular weight sugars (e.g., fructose-glucose syrups and honey), other polyols (e.g., glyceryl derivatives and propylene glycols), lipids and derivatives (e.g., phospholipids, fatty acids, lecithin, oils, and waxes), and water [18]. Some other components, such as cross-linkers and nano-reinforcements, can also be incorporated to improve barrier, tensile, and water resistance properties.

Modern paradigm in edible packaging technology

Materiomic paradigm

The growing understanding of the structure–property–process relations of materials is enabling the design of edible packaging materials with versatile functionalities [14••,23]. Most materials display distinctive hierarchical structures across multiple scales, exhibiting molecular details in multiscale chemical and mechanical behavior. These approaches, to understanding material properties and behavior is known as materiomics, and it is key to