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(Review Article)

Edible films and coatings for innovative use as food protective materials: Review and perspectives

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Abstract

Edible films and coatings produced from renewable biological substances hold promise for innovative use as food protective materials. They should possess the appropriate barrier and mechanical properties and also retain these properties during the commercial marketing of food. Thus, various proteins of plant and animal origin have received much attention in the edible film technology. The objective of this review work was to make, initially, an inventory of the technology of films based on simple biological materials (biodegradable compound and plasticizer) and to arouse the interest to investigate a synergy of all the materials used. Spray drying is also an alternative to explore with the synergized function of multiplasticizers.

Keywords: Biopolymer films; Coating materials; Plasticizers; Food quality; Shelf life

1 Introduction

Edible films and/or coatings are biopolymers that are widely being explored for preservation and packaging of food. Although their use in food products seems new, food products were first covered by edible films and coatings many decades ago. Wax has been used to delay dehydration of citrus fruits in China since the twelfth and thirteenth centuries [1]. Afterwards, edible films and coatings find use in a variety of applications [2-5], including chocolate coatings for nuts and fruits [4-6], wax coatings for fruits and vegetables [7] and active packaging for meat, fish and derived products [8,9]. The technical challenges involved in producing stable foods suggest that edible films and coatings could be used to an even greater extent than they are today.

2 Concept of edible films and coatings

Edible films and coatings are used to extend shelf-life by creating a barrier against the environment as well as providing effective antioxidative and/or antimicrobial properties. An edible film or edible coating can be defined as a thin layer of material which can be eaten by the consumer, can be applied on or within foods by wrapping, dipping, brushing, or spraying [10] and function as selective barriers against the transmission of gases, vapors and solutes [11], and also provide mechanical protection [12]. These mass transfers can happen between foods and their surrounding environment or between components of foods, which result in the reduction of shelf life and food value, and the reduced ability of the food industry to meet increasing consumer demands for higher quality food products [13,14]. Edible films

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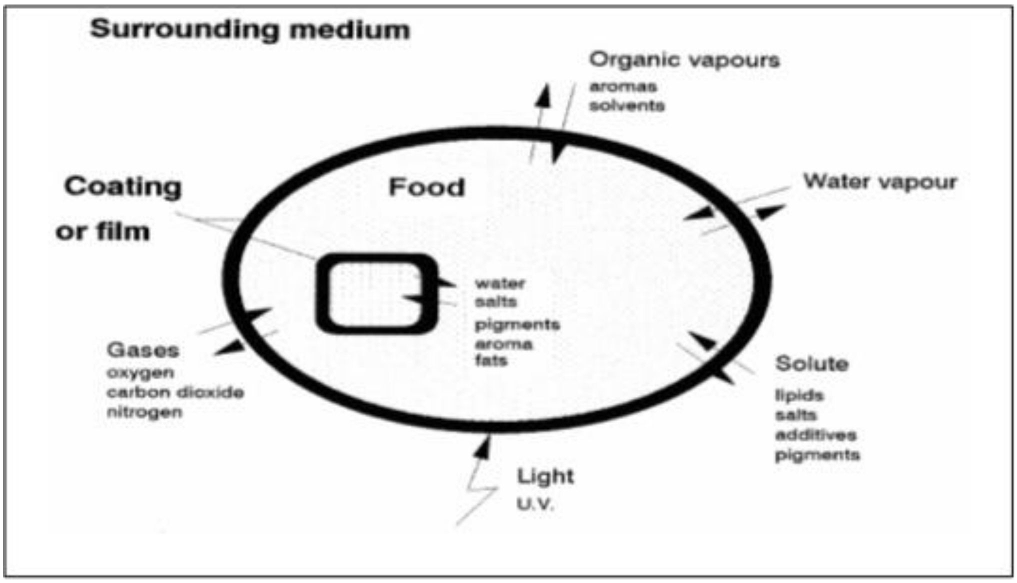
are developed and then added to the food [11,12], whereas coatings are created on the food's surface [6]. Selective properties of edible films and coatings are summarized in Figure 1.

Films are created from a variety of compounds derived from polysaccharides, proteins, lipids, or a combination of these [15]. These compounds are often combined with a solvent such as water or organic acids to help give them functional properties. All films and coatings have both cohesive and adhesive properties which act to hold the film together and hold the film to the food surface, respectively [16].



Adapted from Debeaufort et al. [13]

Figure 1 Selective functions of edible films and coatings

Functional efficiency strongly depends on the nature of components and film composition and structure. The choice of film-forming substance and/or active additive is a function of the objective, of the nature of the food product and of the application method.

3 Use of plasticizers in edible films and coatings

Films made from biodegradable material in general and protein in particular are quite stiff and brittle due to extensive interactions between protein chains through hydrogen bonding, electrostatic forces, hydrophobic bonding and/or disulfide cross-linking hence necessitating the use of plasticizers to increase film flexibility. A plasticizer is defined as "a substantially nonvolatile, high boiling, non-separating substance, which when added to another material changes the physical and/or mechanical properties of that material" [16]. The main role of plasticizers is to improve flexibility, reduce brittleness, and decrease both porosity and tendency to crack. It results of plasticizer addition is a reduction in protein chain-to-chain interactions, and lowering of the protein glass transition temperature(s). Unfortunately, plasticizers generally also decrease the film's ability to act as a barrier to moisture, oxygen, aroma, and oils. Plasticizers that are acceptable and generally used for protein films, include propylene glycol ($C_3H_8O_2$) [17], glycerol ($C_3H_8O_3$) [11,12,18], sorbitol ($C_6H_{14}O_6$) and triethyl citrate (TEC) [18], polyethylene glycol [$H(OCH_2CH_2)_nOH$] [19], sucrose ($C_{12}H_{22}O_{11}$), and/or vegetable oils [20,21]. Water is also an important plasticizer for edible films [22]. Thus, film moisture content, as affected by the surrounding environment's relative humidity (RH), has a large effect on film properties. Glycerol plasticizes effectively due to its ability to reduce internal hydrogen bonding while increasing flexibility of polymer films by decreasing attractive intermolecular forces along the polymer chains and increasing chain mobility [23,24]. Plasticizer can be formulated either with one or more components. Water, glycerol, and sorbitol were used as modal materials to demonstrate the synergized function of multi-plasticizers [22]. The behaviour of sucrose added to aqueous starch film solution, in combination with vegetable oil was also investigated. However, the combination of plasticizes does not always induce positive effects on film properties [21].

4 Protein-polysaccharides edible films and coatings

The continuously increasing interests of consumers in quality, convenience and food safety have encouraged further research into edible films and coatings. Combining polysaccharides and proteins in the form of blends or layers, with varying ratios of polymers, offers the possibility of creating different films with improved characteristics.

Biopolymer films, which contain both protein and polysaccharide ingredients, may advantageously use the distinct functional characteristics of each film-forming ingredient. As reported by some authors, incorporation of polysaccharides into globular protein matrices may extend the functional properties of these ingredients [25,26]. Schmitt et al. [27] have shown that protein-polysaccharide complexes gel more effectively than polysaccharides and proteins in isolation. These effects may be attributed to the simultaneous presence of the 2 biopolymers, as well as to the structure of the complexes. According to Turgeon and Beaulieu [26], heat treatment of a protein-polysaccharide complex weakens the low-energy bonds responsible for co-solubilization of the protein and polysaccharide. After breaking of this equilibrium, a competition occurs between phase separation and protein gelation in the system. When protein gelation is favored by the experimental conditions, a continuous protein network is formed with polysaccharide inclusions, thereby strengthening the complex. Turgeon and Beaulieu [26] strengthened the structure of a whey protein gel by incorporating κ-carrageenan into the gel. From subsequent rheological investigation, they reported that gelation of the 2 components were independent, where the protein gel formed 1st and the κ-carrageenan gel formed during the cooling phase. Zaleska et al. [25] formed gels from pectin and whey protein isolate, and they suggested that anionic interactions may occur between the protein and polysaccharide components if they are electrically compatible. It may therefore be possible to manipulate combinations of polysaccharide and protein component of edible films to adjust water vapor resistance or structural strength.

Few literature reports on the film-forming mechanism of such combinations of protein and polysaccharide. Parris et al. [28] formed films from whey proteins and alginate or pectin and reported that the films formed from protein-polysaccharide blends had lower water-vapor permeability (WVP) than those formed from protein alone. They also suggested that future studies should be directed towards improving the physical properties of films through covalent bonding of proteins and polysaccharides using processing techniques such as spray-drying. Different authors formed gels from separate solutions of polysaccharide or protein powders [25,26], often called dry blending, whereby the individual protein and polysaccharide materials are blended together in powder form. The protein and polysaccharide materials may also be blended by spray-drying solutions of the combined ingredients to form a co-dried, biopolymer powder. This process, known as co-drying, is a novel process; it is believed that combining the powders in such a way may promote increased interaction between the protein and polysaccharide constituents. Schmitt et al. [27] suggested that protein-polysaccharide complexes were formed with a polyelectrolyte chain bounded by several protein molecules. These primary complexes may aggregate during spray-drying to form inter-biopolymer complexes with a structure consisting of several interacting polymer chains. To our knowledge, many data exist in the literature, but not too much enough, on blending ingredients using such co-drying techniques. Consequently, there is a potential to alter the physical properties of hydrophilic films by combining whey protein and polysaccharide components [4,6,12,25,26,27,29] for more investigations.

5 Conclusion

Biopolymer films and coatings made from proteins, polysaccharides, and lipids, formulated either with one or more components have been investigated to show the potential to control food quality and extend shelf life. Various plasticizers were used in protein or polysaccharide films as modal materials to study the plasticizing efficiency and performance under different environmental conditions. The efficiency, stability, and compatibility of each plasticizer, as well as their synergized functions were investigated based on the characterizations of physical, mechanical and tensile properties to provide a better packaging material. From this review work, we suggest that future studies should be directed towards improving the film properties through covalent bonding of proteins and polysaccharides using processing techniques such as spray-drying, combining protein and polysaccharide components on one side, and combination of plasticizers (in synergy) on other side for more investigations.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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