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Review

# Development of edible films and coatings from alginates and carrageenans

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ABSTRACT

The use of renewable resources, which can reduce waste disposal problems, is being explored to produce biopolymer films and coatings. Renewability, degradability, and edibility make such films particularly suitable for food and nonfood packaging applications. Edible films and coatings play an important role in the quality, safety, transportation, storage, and display of a wide range of fresh and processed foods. They can diminish main alteration by avoiding moisture losses and decreasing adverse chemical reaction rates. Also, they can prevent spoilage and microbial contamination of foods. Additionally, nanomaterials and food additives, such as flavors, antimicrobials, antioxidants, and colors, can be incorporated into edible films and coatings in order to extend their applications. Water-soluble hydrocolloids like polysaccharides usually impart better mechanical properties to edible films and coatings than do hydrophobic substances. They also are excellent barriers to oxygen and carbon dioxide. Recently, there has been much attention on carrageenan and alginate as sources of film-forming materials. Thus, this review highlights production and characteristics of these films.



**Contents**



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## 1. Introduction

The quantity of packaging materials has been increasing by 8% annually (Muizniece-Brasava, Dukalska, & Kantike, 2011). Less than 5% of all plastics are being recycled, leading to a high accumulation of plastics in the environment (Espitia, Du, Avena-Bustillos, Soares, & McHugh, 2014). Besides, increasing consumer concerns on food safety led to development of biodegradable, edible, and renewable films and coatings suitable for food and nonfood packaging applications (Alves, Costa, & Coelhoso, 2010; Espitia et al., 2014). However, due to the low cost of synthetic polymers, biodegradable materials had been ignored (Hambleton, Voilley, & Debeaufort, 2011). Today, with traditional agricultural commodities being a source of film-forming material, wide commercialization of biopolymer films has gained more significance (Arvanitoyannis, 2010).

Biopolymers such as polysaccharides, proteins, and lipids can be used for the formation of edible films and coatings (Albert & Mittal, 2002; Espitia et al., 2014; Lee, Shim, & Lee, 2004). They can be used as complement or replacement of traditional materials in order to reduce traditional polymeric packaging (Barreto, Pires, & Soldi, 2003; Mate & Krochta, 1998).

Edibility and biodegradability are the most beneficial characteristics of edible films and coatings. Edibility of films and coatings could be achieved if films and coatings components including biopolymers, plasticizers, and other additives be food grade ingredients. Meanwhile, all the processes and equipment should be acceptable for food processing. To claim biodegradability of films and coatings, their toxicity and environmental safety must be evaluated by standard analytical protocols (Han & Aristippos, 2005).

An edible coating is a thin layer of edible material formed as a coating on a food product (Kang, Kim, You, Lacroix, & Han, 2013), while an edible film is a preformed thin layer, made of edible material, which can be placed on or between food components (Espitia et al., 2014; Guilbert, Gontard, & Gorris, 1996). The main difference between these 2 food systems is that the edible coating is applied in liquid form on the food, usually by immersing the product in the solution of edible material, and edible film is first molded as solid sheets, then applied as a wrapping for food products (Falguera, Quintero, Jiménez, Muñoz, & Ibarz, 2011).

The concept of employing edible films and coatings for foods dates back to 1950s. Their growing application is attributable to reduction of moisture loss, adverse chemical reactions (Baldwin & Wood, 2006; Osorio, Molina, Matiacevich, Enrione, & Skurtys, 2011), spoilage, and microbial contamination (Arvanitoyannis, 2010). Additionally, they can be used for controlled release of food additives (Barreto et al., 2003). Edible coatings are also effective as a post-harvest treatment to preserve fruit quality (Valero et al., 2013).

Hydrophobic substances such as resins, waxes, or some insoluble proteins are better moisture barriers, but water-soluble hydrocolloids like polysaccharides and proteins usually impart better mechanical properties (tensile strength and elongation at break) to edible films and coatings than do lipids and hydrophobic substances (Arvanitoyannis, 2010). They also are excellent barriers to oxygen and carbon dioxide (Nussinovitch, 2009) because of their tightly packed and ordered hydrogen-bonded network structure (Atarés, Pérez-Masiá, & Chiralt, 2011; Bonilla, Atarés, Vargas, & Chiralt, 2012). So, they can be used to extend the shelf-life of foods by preventing dehydration, oxidative rancidity, and surface-browning (Dhanapal et al., 2012). Besides, food hydrocolloids can act as nutritious food ingredients. Some health benefits include lowering risk factors for cardiovascular disease, for immune function, for weight management, and for intestinal problems (Viebke, Al-Assaf, & Phillips, 2014). Table 1 shows the main hydrocolloids that can be used for the preparation of edible films and coatings. The uses of alginates and carrageenans in edible films and coatings are summarized in Table 2.

In recent years, there has been much attention on carrageenan and alginate as sources in edible film formation (Cian, Salgado, Drago, Gonzalez, & Mauri, 2014). According to FDA, carrageenans and alginates are GRAS materials thereby they have been passed the mentioned standards and are considered as edible films and coatings. To the best of our knowledge, there is no review article about carrageenan and alginate films and coatings. Thus, this review highlights production and characteristics of these films.

## 2. Alginate

Alginate is an appealing film-forming compound because of its non-toxicity, biodegradability, biocompatibility, and low price (Vu & Won, 2013). Its functional properties, thickening, stabilizing, suspending, film-forming, gel-producing, and emulsion-stabilizing have been well studied (Dhanapal et al., 2012; Zactiti & Kieckbusch, 2006).

Alginic acid was first discovered in 1881 by Stanford. Around 1923, Thornley, in Orkney, UK, established a briquette business based on using alginate as a binder for anthracite coal dust. He moved to San Diego, USA, and by 1927 his company was producing alginate for use in sealing cans. After some difficulties, the company changed its name to Kelp Products Corp. and in 1929 it was reorganized as Kelco Company. Alginate production was established in the United Kingdom and Norway during 1934 to 1939 and after World War II, respectively (ITC 1981). The 2 largest producers, Kelco Company in the USA and Alginate Industries Ltd, in the UK were

**Table 1**
Main hydrocolloids used for the formation of edible films and coatings (Milani & Maleki, 2012; Skurtys et al., 2010).

| Type of hydrocolloid | Principal function |
|---|---|
| **Polysaccharide** | |
| Agar (E406) | Gelling agent |
| Alginate (E400-404) | Gelling agent |
| Carrageenan (E 407) | Gelling agent |
| Carboxymethyl cellulose (E466) | Thickener |
| Hydroxypropyl cellulose (E463) | Thickener and emulsifier |
| Hydroxypropyl cellulose (E464) | Thickener |
| Methyl cellulose (E461) | Thickener, emulsifier and gelling agent |
| Chitosan | Gelling and antimicrobial agent |
| Arabic gum (E414) | Emulsifier |
| Guar gum (E412) | Thickener |
| Xanthan gum (E415) | Thickener |
| Pectin (E440) | Gelling agent |
| Starches | Thickener and gelling agent |
| **Protein** | |
| Bovine gelatin | Gelling agent |
| Fish gelatin | Gelling agent |
| Pig gelatin | Gelling agent |
| Whey protein | – |