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Review

Environment friendly green composites based on soy protein isolate – A review

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ABSTRACT

As a result of the growing environmental awareness (e.g., increased pollution, increasing demand for biodegradable materials, material need for CO_2 neutrality and low greenhouse gas emissions, new environmental laws and regulations), manufacturers and scientists are keen to study novel environmental friendly materials. Soy protein isolate (SPI), a protein with reproducible resource, good biocompatibility, biodegradability and processability has a significant potential in the food industry, agriculture, bioscience and biotechnology. The aim of this review is to offer a comprehensive view of the recent state of art of eco-materials based on Soy Protein Isolate (SPI) with special reference to organic and inorganic fillers in the macro, micro and nano scale. Moreover, some applications of SPI-based materials, especially in the field of food preservation and packaging technology, are also discussed.

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1. Introduction

In recent years there has been a great interest to utilize renewable biomass (Echeverría, Eisenberg, & Mauri, 2014; Espitia, Du, Avena-Bustillos, Soares, & McHugh, 2014; Fagundes, Palou, Monteiro, & Pérez-Gago, 2014; Farahnaky, Dadfar, & Shahbazi, 2014; Galus & Lenart, 2013; Ghanbarzadeh, Oleyaei, & Almasi, 2014; González & Alvarez Igarzabal, 2013; Guerrero, Garrido, Leceta, & de la Caba, 2013; LaMantia & Morreale, 2011; Mitra, 2014; Nur Hanani, Roos, & Kerry, 2014; Song & Zheng, 2014) in the manufacture of high-quality, cost-competitive and biodegradable consumer goods as a means to reduce the consumption and the dependence on petro-chemical feedstock and to diminish environmental pollution. The substitution of petroleum-based plastics with bio-based plastics in the manufacture of packaging and biomedical materials will reduce the dependency of plastics on fossil fuels and the pressure on landfills from plastic solid wastes (Álvarez-Chávez, Edwards, Moure-Eraso, & Geiser, 2012). Thus, around the world many scientists have focused their research on using materials from nature. The ideal biodegradable packaging materials are obtained from renewable biological resources, usually called biopolymers, with excellent mechanical and barrier properties and biodegradability. Biopolymer or biodegradable plastics are polymeric materials in which at least one step in the degradation process is through metabolism of naturally occurring organisms (Rhim, Park, & Ha, 2013). In particular, packaging films and containers made of natural biodegradable polymers are of particular interest due to their compostability, since most of these products have a relative short service life ending up in landfills. In this sense, protein-based materials have been proved to be completely degrading in 50 days when buried in farmland soils (Félix, Martín-Alfonso, Romero, & Guerrero, 2014). Therefore, the development of biodegradable biopolymer-based materials cannot only solve the “white pollution” problem but also ease the over-dependence on petroleum resources (Song, Tang, Wang, & Wang, 2011).

Biopolymers from food resources meet the growing worldwide need for eco-friendly, sustainable materials (Saenghirunwattana, Noomhorm, & Rungsardthong, 2014; Sirviö, Kolehmainen, Liimatainen, Niinimäki, & Hormi, 2014) (Chen, Remondetto, & Subirade, 2006; Chiellini, Barghini, Cinelli, & Ilieva, 2008; Ghavidel, Davoodi, & Adib, 2013; Huang & Netravali, 2009), offering alternative packaging option with excellent biodegradability and a relatively low cost. There are two types of biodegradable polymers; edible and non-edible. Synthetic films made from polyethylene, polyvinylchloride, polyamides etc are examples of non edible food packaging. Biodegradable materials derived from food ingredients such as polysaccharides, proteins and lipids are edible and have attracted considerable interest in recent years due to their potential abilities to replace traditional plastics and to act as food contact edible films and/or coatings (Nur Hanani et al., 2014). A major objective in preparing films for many foods (e.g., fresh fruit and vegetables) is to ensure that the generated films afford physical and chemical properties necessary to maintain transmission of various gases and liquids at the same rates as they occur within their native systems (Nandane & Jain, 2014). In addition, edible coatings have been studied for extending shelf life of some fresh fruits so as to prevent enzymatic browning of fresh-cut fruits and vegetables (Ghavidel et al., 2013; Ghidelli, Mateos, Rojas-Argudo, & Pérez-Gago, 2014).

2. Biodegradable composite films based on proteins

Films, casings and coatings made from polysaccharides and proteins are effective barriers against oxygen (O_2), carbon dioxide (CO_2) and low polarity compounds. In comparison with polysaccharide films, protein films show considerably lower O_2 and CO_2 permeabilities and CO_2/O_2 permeability ratio (Kaewprachu & Rawdkuen, 2014; Taylor, Song, & Zheng, 2014). An additional advantage is that proteins can be processed by diverse methods such as dissolution-solvent evaporation or thermo-mechanical methods to produce films with excellent oxygen barrier properties and suitable mechanical properties (Ciannamea, Stefani, & Ruseckaite, 2014). The unique structure of proteins (based on 20 different monomers) provide a wider range of functional properties, especially a high intermolecular binding potential which can form bonds at different positions (González, Strumia, & Alvarez Igarzabal, 2011). The secondary, tertiary and quaternary structures of proteins result in various interactions and bindings, differing in position, type and energy (Silva et al., 2014), and the mechanical properties of protein-based edible films are also better than those of polysaccharide and fat-based films. One of the main research areas in food packaging has focused on developing new packaging techniques capable of improving food preservation properties based on their interaction with packaging. Such techniques are known as “active packaging systems”. An active packaging can be defined as a type of material that changes its packaging conditions to extend shelf life, interacting directly with the food, enhancing security and maintaining quality. In particular, the antimicrobial packaging is one of the most innovative and promising active packaging types developed over the last decade, which includes systems capable of inhibiting microorganism action and avoiding loss of food quality (González & Alvarez Igarzabal, 2013). Previous literature have shown that protein coatings on films would require relatively lower amounts of added antimicrobial agents to reach the desired effect as compared to the synthetic polymer or to other biopolymer films (Zhao, Yao, Fei, Shao, & Chen, 2013). Therefore, numerous proteins such as corn zein, wheat gluten, soy, peanut, cottonseed, sunflower, rice bran, serum albumin, egg white, collagen, gelatin, myofibrils, casein, and whey proteins have been studied as potential film-forming agents (Kumar & Gupta, 2012). Also, these protein films can be blended with other proteins (Bai, Xu, Liao, & Liu, 2013), polysaccharides (Li, Wei, Fang, Zhang, & Zhang, 2013) and lipids (Guerrero, Nur Hanani, Kerry, & de la Caba, 2011) to form composite films. In addition, a new class of materials represented by bio-nanocomposites with enhanced barrier, mechanical and thermal properties has also been considered as a promising option in improving the properties of these biopolymer-based packaging materials. The main objective of producing biocomposite and bionanocomposite films is to improve the permeability or mechanical properties as dictated by the need of a specific application and to replace synthetic plastic products and to make the environment free of plastic wastes (Behera, Avancha, Basak, Sen, & Adhikari, 2012). Among these biodegradable protein films, soy protein-based films possess high potential