Fabrication of gelatin–laponite composite films: Effect of the concentration of laponite on physical properties and the freshness of meat during storage

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ABSTRACT

The biodegradable and biocompatible gelatin–laponite composite films were developed in this study. The effect of the concentration of laponite on the physicochemical properties of the gelatin–laponite film was investigated. The results suggested that the gel strength, mechanical properties, water vapor permeability and water solubility of gelatin–laponite composite films are significantly improved with the increase of the concentration of laponite. In addition, the microstructures of gelatin–laponite films were also characterized by scanning electron microscope (SEM) micrographs. The results of fourier transform infrared spectroscopy (FTIR) indicated that laponite facilitated the conformational changes of proteins films. Furthermore, gelatin–laponite films exhibited substantial enhancement of the quality of meat during storage, which was improved with the concentration of laponite. Hence, gelatin–laponite composite films could be potentially utilized in the development of the novel packaging material in food industries.

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1. Introduction

The development of biodegradable and biocompatible materials from renewable resources will profoundly affect economic and environmental future globally. The stress of oil depletion is fundamentally limiting the availability of petroleum based plastic materials in recent decades (Feng & Ye, 2013). Thus, renewable-oriented strategies regarding the manufacture of packaging materials could lead to crucial reductions in non-renewable energy consumption and greenhouse gas emissions. To fulfill the compliance goal, a broad spectrum of edible polymers has been employed to produce or synthesize polymer matrices, composite films and nano-delivery system, such as polysaccharides (Feng et al., 2014, 2013; Feng, Ye, Zhuang, Fang, & Chen, 2012), proteins (Chen, Ye, Li, & Wang, 2013; Chen, Ye, & Liu, 2013, 2014; Wang, Liu, Ye,

Wang, & Li, 2014; Ye & Harte, 2013, 2014) and lipids (Hayes et al., 2012; Ye & Hayes, 2012a, 2012b; Ye, Hayes, & Burton, 2014; Ye, Pyo, & Hayes, 2010; Zhao et al., 2014). Gelatin is a colorless and flavorless mixture of polypeptide and protein (Chen, Ye, & Wang, 2014; Wang et al., 2014), obtained from various inexpensive animal origins. Due to the high water binding capacity, the film-forming ability and emulsifying properties, gelatin has been widely utilized in food, cosmetic and pharmaceutical industries (Wang et al., 2014). In general, gelatin is considered as a promising candidate for the development of gelatin-based composite films by blending with, clay nanocomposite (Bae, Darby, Kimmel, Park, & Whiteside, 2009) (Rao, 2007), montmorillonite (Bae, Park, et al., 2009), montmorillonite derivatives (Farahnaky, Dadfar, & Shahbazi, 2014; Kanmani & Rhim, 2014), and ZnO nanorods (Rouhi, Mahmud, Naderi, Ooi, & Mahmood, 2013).

Laponite (hydrous sodium lithium magnesium silicate, $Na_{+0.7}[(Si_8Mg_{5.5}Li_{0.3})\,O_{20}\,(OH)_4]_{-0.7}$) is a unique sort of white synthetic layered silicate clay formulated from inorganic minerals, with diameter in the range of 25–30 nm and thickness of 1 nm (Kroon, Vos, & Wegdam, 1998; Shahin & Joshi, 2012). Since laponite nano-clays carry negatively charged face and positively charged edges, they could be readily dispersed in water in a state of disk-shaped crystal colloids (Thompson & Butterworth, 1992). When

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the concentration of laponite nano-clays is reaching upon ~2% (w/v), they accumulate together through interparticle electrostatic forces followed by the transition from the homogenous sol particle to a soft gel (Pawar & Bohidar, 2009). Laponite has received substantial attention due to the unique physical behavior, biodegradability and biocompatibility with a wide range of industrial applications, for instance, surface coatings, personal care products, and household products etc,.

In literature, the biohybrid elastic coacervates of fish gelatin/Laponite, including phase separation kinetics, composition, internal structure, and viscoelastic properties, have been reported (Karimi, Taheri Qazvini, & Namivandi-Zangeneh, 2013). Another research evaluated the effect of the addition of laponite, montmorillonite, and chitosan on the melting of gelatin gels (Prado & Vyazovkin, 2014). However, little information is released from literature regarding the comprehensive understanding of physicochemical properties of gelatin–laponite film and its application in food storage. In the present paper, the primary objective is to manufacture the gelatin–laponite film. The secondary objective is to study the physicochemical properties of the gelatin–laponite film consisting of the mechanical and water resistance properties, microstructures. Furthermore, the antioxidant activities of the nanocomposite films were evaluated.

2. Material and methods

2.1. Chemicals

The commercial type A bovine-hide gelatin (Bloom 220) was purchased from Tianxin food additives company (Qingdao, China). Laponite was kindly donated by Yuanye company (Tianjin, China). NaCL, HCL, glycerin, and Tris–HCl were obtained from Sigma--aldrich (Shanghai, China). All commercial chemicals were all analytical grade and used without further purification.

2.2. Films preparation

Gelatin powder was slowly added into Millipore water at 40 °C and stirring for 2 h. After cooling, the pH of the stock solution of 10% (w/v) gelatin was adjusted to 4.0 in the presence of 60 mM of NaCL. A homogenous and optically transparent dispersion of laponite was prepared by mixing laponite with Millipore water for 2 h. Finally, the gelatin stock solution was gently mixed with the laponite dispersion at 250 rpm for 1 min at the ratio of 5:1, 10:1, 15:1, 20:1, respectively. The film stock solution contained 5% (w/v) of gelatin and 40% (w/w) of glycerol. Afterward, the stock solution was immediately cast onto polyacrylic plates (11 cm × 11 cm) following by the oven-dry treatment for approximately 5 h at 30 °C. The prepared films were removed and maintained in a desiccator for 48 h at 25 °C and 51% relative humidity (RH), using saturated magnesium nitrate ($MgNO_3 \cdot 6H_2O$) solution. All experiments were performed immediately after being taken out from the chamber for minimizing the moisture variance of films.

2.3. Film thickness

Film thickness was evaluated using a hand-held micrometer (Mitutoyo No. 293-766, Tokyo, Japan) with a precision of 0.001 mm. Measurements were conducted at ten different locations in the film.

2.4. Gel strength and viscoelastic properties

The stock solutions of gelatin–laponite were cooled in a refrigerator at 4 °C for 1 day. Gel strength was evaluated by the

published methodology using a Texture Analyzer (Stable Micro Systems Ltd, UK) with a cross head rate of 1 mm/s and equipped with a P/0.25 S flat faced cylindrical plunger (Wang et al., 2014).

Frequency sweep tests (mechanical spectra) from 0 to 50 Hz were performed at 40 °C for stock samples of all the varieties. The storage modulus (G′), loss modulus (G″) of stock solution samples were measured with the change of frequency.

2.5. Mechanical properties

A Texture Analyzer (Stable Micro Systems Ltd, UK) was employed to measure the mechanical properties, following the published protocol (Wang et al., 2014) with minor modifications. The films were cut into the rectangular test strips with a length of 70 mm and a width of 25 mm, and the cross-head speed was set at 20 mm/s. Tensile strength was calculated by dividing the maximum load at break by the area of cross-section and expressed in MPa. Elongation at break (E, %) was expressed as:

$$E = 100 \times \frac{L_1 - L_0}{L_0} \tag{1}$$

where L_0 (mm) is the initial length of the film and L_1 (mm) is its length at break.

2.6. Water vapor permeability

The WVP of the gelatin–laponite films was recorded on the basis of the method reported in literature (Wang et al., 2014). The gelatin film was cut to 2 cm in diameter, and the film was employed to seal a testing cup containing anhydrous calcium sulfate. The films were equilibrated for 1 h before the cells were initially weighed. Thereafter, the weight of the cup was measured intermittently at intervals of 24 h, up to 96 h. WVP of the films was calculated as follows:

$$WVP = \frac{W \times L}{t \times A \times P} \tag{2}$$

where WVP = water vapor permeability ($\times 10^9$ g m/m$^2 \cdot$s$\cdot$Pa), W = increase in cup weight (g), L = thickness of film (m), t = measuring time (s), A = measuring area (m^2), and P = difference in pressure between outside of the cup and inside of the cup (Pa).

2.7. Water solubility

The method described by the previous study (Wang et al., 2014) was employed to determine water solubility of the films. Film samples were stored for 7 days in the 0% RH desiccator before testing. Samples were placed in the test beakers, and dried to the constant weight in a 50 °C oven at the nearest 0.0001 g. After adding 15 ml distilled water in each beaker, samples were placed at room temperature with periodical gentle manual agitation for 24 h. The remaining pieces of films were taken out and dried again in an oven at 50 °C until they reached a constant weight. The percentage of total soluble matter (% solubility) was calculated as follows:

% Solubility = (Initial dry weight

      − Final dry weight)*100/Initial dry weight