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# Role of ferulic acid in preparing edible films from soy protein isolate

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**Abstract**

Different concentrations of ferulic acid were added to film-forming solutions when preparing soy protein isolate-based edible films. The results showed that an optimal concentration of ferulic acid increased the tensile strength, elongation percentage at break and antioxidant activity of films for preservation of fresh lard. The optimal concentration for ferulic acid in film forming solution is 100 mg/100 g. Moreover, the properties of the film were further improved when ferulic acid was oxidized by hydrogen peroxide. A possible mechanism for the role of ferulic acid in the preparation of SPI-based films is that it reacted with amino acids and increased cross-linking of the protein. It is interesting that the absorbance wavelength for ferulic acid-protein (or amino acids) is much longer than ferulic acid or protein (or amino acids) alone. The absorbance shift indicates the formation of a ferulic acid-protein cross-link that may enhance the shelf life of foods by decreasing oxygen permeability.


*Keywords:* Ferulic acid; Soy protein isolate; Edible film

## 1. Introduction

Packaging is a necessary step for preserving the organoleptic, nutritional and hygienic characteristics of food during storage and commercialization. The wide variety of packaging films can be divided into synthetic and edible or biodegradable. Constant progress in the technology of synthetic film preparation has expanded and supported their utilization in the food industry. However, most synthetic films are petrochemical-based and non-biodegradable, leading to environmental pollution and serious ecological problems (Tharanathan, 2003). In contrast, edible films use renewable resources as raw materials and are biodegradable, making them more compatible with the environment. Additionally, other adjuncts such as antimicrobials, antioxidants, nutrients, colorants, etc. are easier to add to edible films, thus further enhancing their protective functions.

Edible films can be prepared from proteins, polysaccharides, lipids or the combination of these components (Gontard & Guilbert, 1994). Among them, proteins-based edible films are the most attractive. These films have impressive gas barrier properties compared with those prepared from lipids and polysaccharides. When they are not moist, the $O_2$ permeability of soy protein-based film was 500, 260, 540 and 670 times lower than that of low-density polyethylene, methylcellulose, starch and pectin respectively (Cuq, Gontard, & Guilbert, 1998). The mechanical properties of protein-based edible films are also better than that of polysaccharide and fat-based films because proteins have a unique structure (based on 20 different monomers) which confers a wider range of functional properties, especially a high intermolecular binding potential (Cuq, Aymard, Cuq, & Guilbert, 1995). Protein-based edible films can form bonds at different positions and offer high potential for forming numerous linkages.

Unfortunately, SPI films do not show satisfactory mechanical properties or vapor barrier properties for practical applications, and these properties become even

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poorer under conditions of high humidity (Gontard, Guilbert, & Cuq, 1993). It was reported that the addition of cross-linking agents into film forming solutions or other physical methods might improve the mechanical properties and water vapor permeability of protein-based edible films. The cross-linking agents include gossypol, formaldehyde, glutaralaldehyde (Marquie, Aymard, Cuq, & Guilbert, 1995), calcium salts, gluconо-δ-lactone, carbodiimide, acetylated monoglyceride and transglutaminase (Mariniello et al., 2003; Morel, Bonicel, Micard, & Guilbert, 2000; Park, Rhee, Bae, & Hettiarachchy, 2001), and thiol oxidation (Anker, Berntsen, Hermansson, & Stading, 2002). The physical methods include ultrasound or $\gamma$-irradiation treatment (Banerjee, Chen, & Wu, 1996; Sabato et al., 2001). However, there are no reports on the cross-linking properties of ferulic acid in the preparation of edible films, although it is a cross-linking agent in plant cell walls (Liyama, Lam, & Stone, 1984).

Ferulic acid, a health component of food with multiple phytochemical functions (Ou & Kwok, 2004), is a phenolic acid derivative existing ubiquitously in the plant kingdom. It can cross-link with protein and polysaccharides by producing a resonance-stabilized free radical intermediate (Hopkins et al., 2003; Oudgenoeg et al., 2001). Ferulic acid was used to prepare satisfactory gels from arabinoxylans and proteins or pectin (Figueroa-Espinoza et al., 1999; Oosterveld, Beldman, & Voragen, 2000).

As the quinone, (oxidized ferulic acid), it can react with amino and thiol groups in protein (Figueroa-Espinoza et al., 1999). Additionally, the free radical formed from ferulic acid can react with tyrosine and with itself to form diferulic acid (Oudgenoeg et al., 2001; Vansteenkiste, Babot, Rouau, & Micard, 2004), which act as a bridge between protein molecules. This suggests that ferulic acid could act as a satisfactory cross-linking agent in preparation of protein-based edible films.

Our previous preliminarily research proved that ferulic acid could increase the mechanical properties of edible films prepared from soy protein isolate (Ou, Kwok, & Kang, 2004). In this study, the effect of the addition of different amounts of ferulic acid to the film forming solution was determined on both the mechanical properties and water vapor permeability of the films. Additionally, the $O_2$ barrier properties of the films were determined by measuring the antioxidant properties of the film in preventing the oxidation of fresh lard.

## 2. Materials and methods

### 2.1. Materials

Soy protein isolate (SPI) with protein content 93% was purchased from Hong Kong Advanced Science and Technology Co. Ltd (Hong Kong); Glycerol, ferulic acid and amino acids, including cysteine, lysine, tyrosine, phenylalanine, arginine, serine, tryptophane were purchased from Sigma Chemical CO, St Louis, MO, USA; Hydrogen peroxide (33%) from the Guangzhou Chemicals Company Ltd (Guangzhou, China).

### 2.2. Preparation of film added with ferulic acid

Film forming solution was prepared as follows: 5.0 g soy protein isolate (SPI) was dispersed in approximately 50 ml deionized water by constant stirring, 3.0 g glycerol was added, and different amounts of un-oxidized or oxidized ferulic acid (50, 100, 150, 200 mg respectively). The total weight of each solution was adjusted to 90.0 g with deionized water, the pH was adjusted to 8.0 and 9.0 respectively using 0.1 mmol/L NaOH and HCl, and then deionized water was added to a final weight of 100.0 g.

The film forming solution was heated for 30 min at 85 °C in a water bath under constant stirring at 150 rpm, then cooled to room temperature. 16.0 g portions of the film forming solution were poured into a polyethylene box ($20 \times 20 \times 1$ cm) and kept at 50 °C for 24h in an oven, then cooled, and finally the film was conditioned in a desiccator over saturated $Mg(NO_3)_2$ solution at 25 °C, 50% RH for 48 h.

Thickness of the films was measured with a micrometer with a sensitivity of 0.001 mm. Films were cut into $2.0 \times 6$ cm pieces and the thickness of each film was measured at five random positions.

Oxidized ferulic acid: Ferulic acid (50, 100, 150, 200 mg respectively) was mixed with 50 ml of 500 mg/L hydrogen peroxide and kept at room temperature for 30 min, then the pH was adjusted to 9.0 to remove residual hydrogen peroxide. SPI and glycerol were added and the pH was adjusted according to the method described above, deionized water was added to a final weight of 100.0 g.

### 2.3. Determination of mechanical properties of films

Tensile strength and percentage elongation at break (TE) were determined according to Jangchud & Chinnan (1999) with a TA500 model Texture Analyzer (Harvey, Main & Co. LTD). Films were preconditioned at 50% relative humidity for 48 h at 25 °C. Five replicate samples, $2.0 \times 4$ cm, for each kind of film were tested.

### 2.4. Water vapor permeability

Water vapor transmission of films was measured using the ASTM method (ASTM, 1993). Circular glass cups with a diameter of 3 cm and depth 4 cm were used. After placing 3 g of dried $CaCl_2$ in each cup, they were