Preparation and Properties of Porcine Plasma Proteins-Polysaccharide Composite Films

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Abstract

Plasma proteins isolated from porcine blood slaughterhouse and polysaccharides including pectin carboxymethylcellulose and carrageenan were used as the raw materials for producing composite films. The concentration of each carbohydrate was varied from 2% to 8% (w/w plasma proteins). The composite films were examined by means of mechanical, moisture barrier and apparent opacity properties. The film microstructures were also investigated by using scanning electron microscopy. The application of plasma proteins-pectin film to cake wrapping showed better microbial reduction performance than PVC-wrapped and unwrapped controls.

Keywords: plasma proteins, polysaccharide, composite film, food wrapping

1. Introduction

Chemically synthesized polymeric films are widely used for packaging in the food industry, because they are easily and inexpensively produced from uniform raw materials and are flexible as well as durable. A serious disadvantage of these films is that they are not biodegradable. On the contrary, films with edible components are biodegradable and have substantial possibilities for enhancing the stability and quality of foods. They also result in significantly reducing the packaging waste [1].

We have investigated the possibility of producing biodegradable films using porcine plasma proteins (PPP) in combination with anionic polysaccharides, including citrus pectin with a 69-74% degree of esterification, carboxymethyl cellulose sodium salt with a degree of substitution 0.60-0.95 and κ-carrageenan. We expected that the plasma proteins-carbohydrate composite films might advantageously have distinct functional characteristics of each film-forming ingredient. The films were analyzed for their microstructures and characterized for their mechanical and physical properties. The potential use of the composite films for food preservation was also investigated.

2. Materials and Methods

2.1 Blood Collection and Porcine Plasma Proteins Preparation

Porcine blood was collected at the breeding line of a municipal slaughterhouse in Phitsanulok province, Thailand. The blood with 0.6% sodium citrate as an anticoagulant was transported in closed plastic containers. Once in the laboratory, the plasma proteins were separated from red blood cell concentrate by centrifugation at 5000 rpm and 4°C for 15 min. The plasma proteins were dehydrated by the spray-dry method. Plasma protein powder was kept in a sealed polyethylene bag at 4°C until further use.

2.2 Film Formation

In order to study the effect of type and concentration of carbohydrate on the properties of porcine plasma proteins (PPP)-carbohydrate composite films, the concentration of PPP was kept constant at 5% (w/v), while the amounts of citrus pectin, carboxymethylcellulose (CMC) or carrageenan were varied between 2% to 8% (w/w PPP). The mixture of PPP-polysaccharide solutions were added with a mixture of 30% (w/w PPP) glycerol and 10% (w/w PPP) polyethyleneglycol 400 (PEG 400) as the compatible plasticizers and heated at 95°C for 30 min. Films were cast by pouring 5.0 ml of solution onto 8.6 cm internal diameter Petridishes and dried at the room condition (30±2°C, 60±5% RH) for approximately 24 h. Then, the films were peeled off.

2.3 Film Property Measurement

Thickness of films was determined using a micrometer at 10 random positions around the films, and average values were used in calculations. A gravimetric modified cup method based on ASTM E96-80 [2] was used to determine water vapor permeability (WVP) and calculated as described by McHugh et al. [3]. The tensile strength (TS) and percentage of elongation at break (%E) as evaluated in a tensile test based on ASTM D882-95 [4], were performed using an Instron Universal Testing Machine (Model 4414, Canton. Mass.,USA). Initial gap separation and crossheaded speed were set to 50 mm and 0.5 mm/s. The film transparency, expressed as the apparent opacity, was measured by an absorbance spectrum [5].

2.4 Scanning Electron Microscopy (SEM)

SEM was used to characterize the film surfaces and cross-sections. The samples were examined in a model Leo 1455 Vp scanning electron microscope. Pieces of 6 mm x 1 mm were cut from the film, mounted on stub, and gold coated by Sputter coating Sc-7620.

2.5 Wrapping Assessment

The samples of sliced sponge cake (25 g) were cut into squares. Cake samples were wrapped in PPP-pectin or commercial PVC films. One set of control samples was stored without film at room conditions (30±2°C, 60±5% RH) for 8 days. The hardness of cake texture was measured using the Instron Universal testing instrument (Model 4414, Canton. Mass., USA) for 0, 2, 4, 6 and 8 days of storage. Microbial reduction performance was evaluated at the 6-day storage.

3. Results and Discussion

All PPP-carbohydrate composite films were peelable from the casting surface without observing any damage when they were folded. Average values for film thickness were 45.21 ±1.15 μm and were not significant different ($P>0.05$). The composite films were transparent, with homogeneous texture, and easy to handle at room condition. However, the incorporation of carbohydrates caused a decrease in film transparency (Figure 1a), which is an important property in terms of consumer

acceptance of the films for food wrapping application. Thus, there is a limit of using these carbohydrates at high concentration.

The mechanical study has shown that the incorporation of all tested carbohydrates into the PPP network considerably increased the film strength. The maximum increase of TS value was obtained for the film containing 2% carrageenan. It was greater than that obtained for the control film by 70.45% (Figure 1b). Whereas film extensibility was the greatest in the film with CMC (indicated by trends). The addition of pectin and CMC at a concentration of 2% resulted in significant increases of the elongation by about 12% (Figure 1c).

However, all tested carbohydrates did not improve the moisture barrier property of the composite films. Significant increases of WVP values were observed when increasing the concentration of carbohydrates (Figure 1d). In contrast, Parris et al. [6] formed films from whey proteins and alginate or pectin and reported that the films had lower WVP than those formed from protein alone.

The differences in gel formation and interactions between PPP and each of the polysaccharide components, were responsible for the formation of the structural matrix and their properties [7]. Coughlan et al. [8] suggested that when protein gelation is favored by the experimental conditions, a continuous protein network is formed with polysaccharide inclusion, thereby strengthening the complex. However, the overall characteristics of the films depends not only on the properties of proteins and polysaccharides, but also on the nature and strength of protein-hydrocolloid interactions [9].

As compared to a commercial PVC film by using the same determined conditions, the elongation value of the PVC film, 172.00% ±12.10, was higher than that obtained from the PPP composite film with 2% pectin by only 1.27-fold. However, WVP value of PVC film was 0.35 ± 0.04 $x10^{-4}$gmm/m^2hrkPa, which was considerably lower than that of the PPP-composite film. The microstructure analyses indicated a clear difference between PPP-carbohydrate composite (Figure 2a-c) and PVC films (Figure 2d), which could explain the higher WVP values of composite films as compared to PVC film. According to Chen [10], the simple linear polymeric chains of synthetic polymers can be firmly packed, whereas molecules with voluminous chains of natural polymers are more loosely packed, presenting greater permeability.

The potential use of PPP-carbohydrate composite films as the food wrapping materials to prevent hardening of sponge cake during short-term exposure was carried out using the PPP-pectin (2%) film. It could significant reduce the hardness of the cake by 20% compared to the cake without wrapping at 6 days of storage at room conditions (Figure 3a). Furthermore, it caused a reduction in total plate count bacteria, and yeasts and moulds by 1.69 and 3.6 log CFU/g, as compared to the unwrapped control. The amounts of microbial of PPP-pectin wrapped samples were also much less than those from the PVC-wrapped samples.

4. Conclusion

The results indicate that the plasma proteins isolated from porcine blood slaughterhouse are an attractive raw material for edible film production. The effective utilization of this byproduct would not only represent economic gains, but also reduce pollution and public health concerns about waste. There is potential to improve the mechanical property of the PPP film by incorporating pectin, CMC or carrageenan into the film formulation. However, this study only served to highlight the potential film-forming ability of PPP-polysaccharide

combination and the potential for food preservation.

5. Acknowledgement

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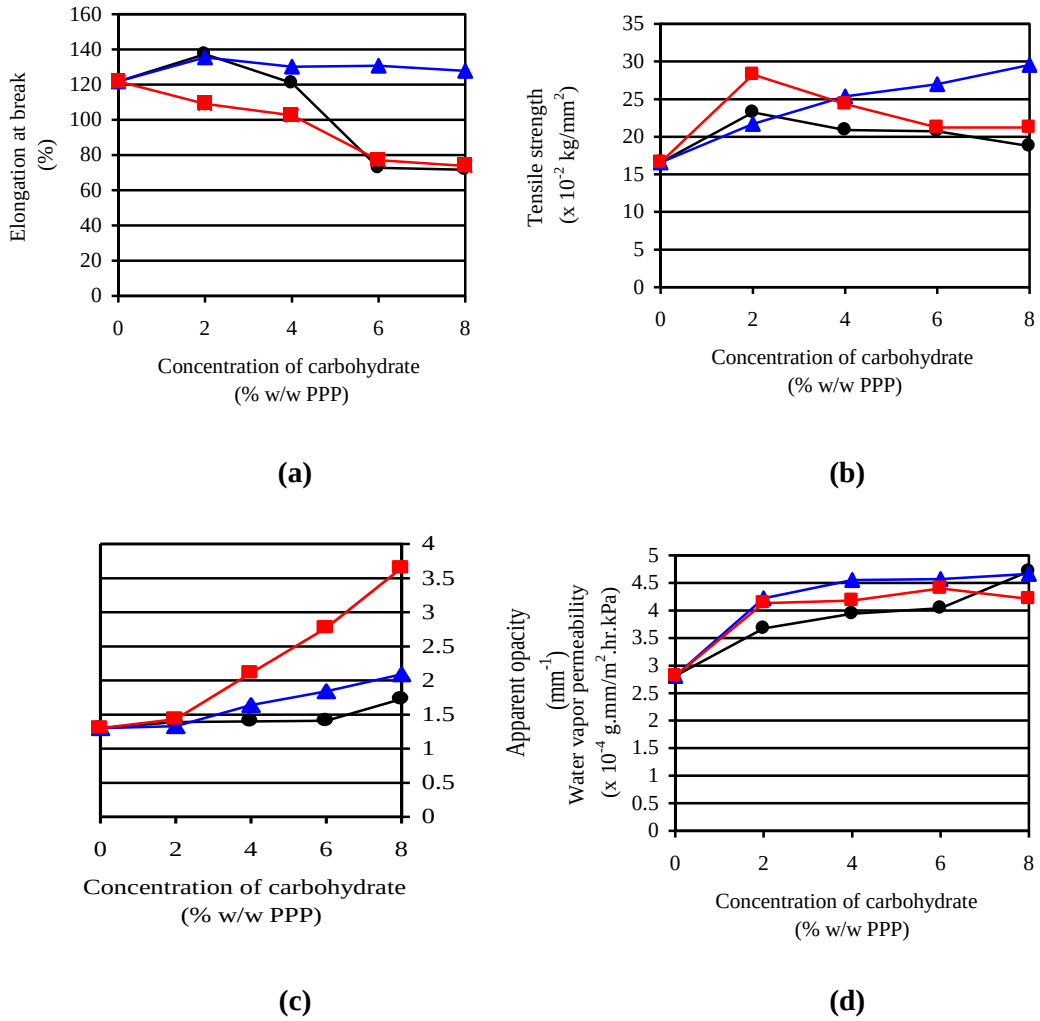


Figure 1 Effect of pectin (#), carboxymethycellulose (%) and carrageenan (!) on (a) apparent opacity, (b) tensile strength, (c) elongation at break and (d) water vapor permeability of the PPP-carbohydrate composite films.

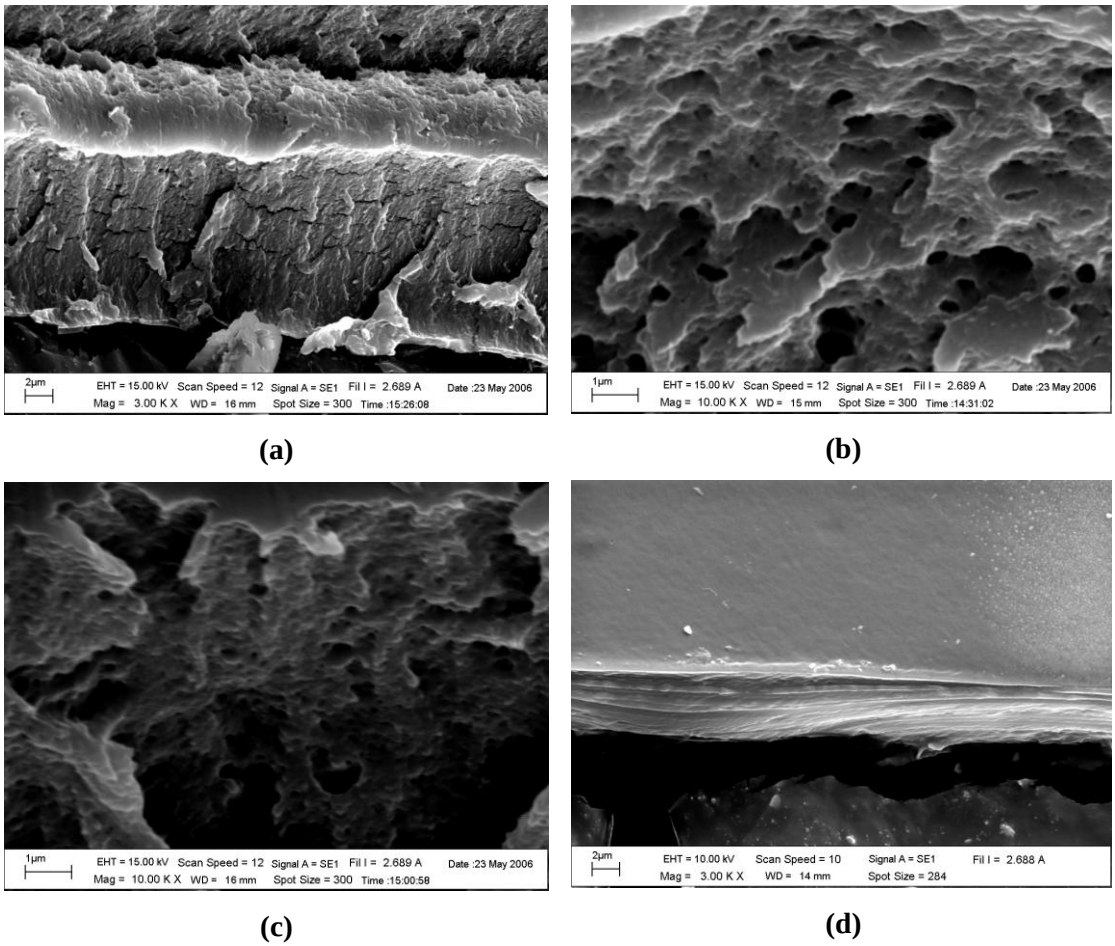
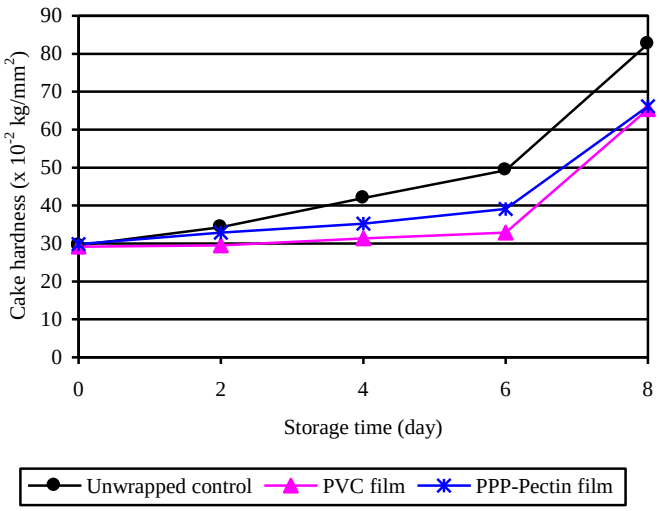


Figure 2 Electron scanning micrographs of the PPP film with (a) 2% pectin, (b) 2% carboxymethylcellulose (c) 2% carrageenan and (d) the PVC film

(a)



(b)

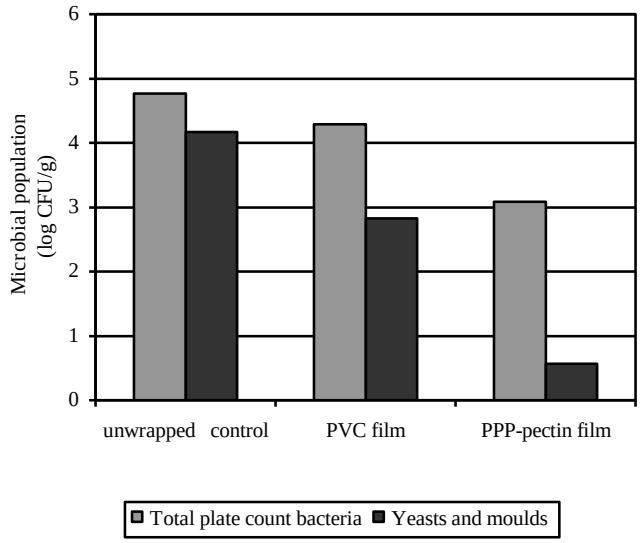


Figure 3 The influence of different wrapping materials on (a) cake hardness during storage at room conditions (30±2^{o}C and 60±5%RH) for 8 days and (b) microbial reduction performance of the cake samples at 6 days of storage, as compared to unwrapped control.