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Functional and pasting properties of pea starch and peanut protein isolate blends

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ABSTRACT

The functional and pasting properties of pea starch (PS) and peanut protein isolate (PPI) blends mixed at different proportions were studied. With the increasing ratio of PPI in PS/PPI blends, the solubility of the blends determined at 90 °C was increased from 16.38 to 31.28% whereas both of the water absorption capacity and the swelling power decreased. The pasting temperature of the blends increased from 72.5 to 77.5 °C while the peak viscosity decreased from 276.33 to 39.92 RVU upon the increasing level of PPI. The hardness of the PS/PPI blends gel decreased from 9.67 N to 0.96 N when the PPI content was increased from 0 to 50% in the blend. Scanning electron microscopy exhibited a honeycomb feature at the ratio of 90:10 and 80:20. The large fragmentary structure of the blending gels was formed at the ratio of 70:30 and became more loosed with the increased ratio of PPI in the blends.

1. Introduction

Peanut is one of the largest oilseeds in the world with 29 million metric tons produced every year (Zhang, Lu, Yang, Li, & Wang, 2011). China is one of the largest producers of peanut, accounting for 46.5% of total peanut production worldwide (Jamdar et al., 2010). Peanut seed contains 25–29% protein, 20–23% carbohydrate and 40–50% oil (Latifa, Pfannstielb, & Makkara, 2013). Defatted peanut flour is a byproduct generated after extracting oil from peanuts, which contains 47–55% of proteins, but with poor functional properties (Yu, Aahmedna, & Goktepe, 2007). However, peanut protein isolate (PPI) (a product prepared by alkali extraction and acid precipitation of defatted peanut flour), has higher purity of proteins and better functional properties than other peanut protein products such as flour or concentrate (Wu, Wang, Ma, & Ren, 2009). Combining PPI and starch would be an attractive method to develop new products.

Pea starches (PS) are characterized by high amylose content, mostly ranging between 30% and 60% with varying species (Hoover, Hughes, Chung, & Liu, 2010). Therefore, pea starch is a very useful film-forming material due to its high amylose content which can improve mechanical strengths, including tensile strength (TS) and gas barrier properties. However, pea starch (PS) is mainly used in industrial applications and not much in food applications because of its poor functional properties.

Blends of starch and protein can overcome the shortcomings of their individual characteristics thus are widely used in food products to improve their texture or functional properties (Zhang, Ismail, & Cheng, 2010). In addition, for biopolymer food packages such as edible films, biopolymer interactions play an important role in determining their functional and mechanical properties (Phan, Debeaufort, Voilley, & Luu, 2009).

To the best of our knowledge, there are no reports on the functional and pasting properties of PS/PPI blends. This partly stimulated this research. Data obtained from this study might be useful for future food formulations as well as in edible film preparations.

2. Materials and methods

2.1. Materials

Pea starch (PS) was purchased from the National Starch and Chemical Co. Ltd. (Shanghai, China). The defatted peanut flour was kindly provided by Changshou Group Co. Ltd. (Shandong, China). The protein, lipids, ash, crude fiber, moisture and amylose contents of the pea starch were 0.25%, 0.10%, 0.05%, 0.82%, 10.82% and 39.89%, respectively. The protein, fat, crude fiber, and carbohydrate contents of the defatted peanut flour were 51.8%, 8.0%, 10.5% and 29.7%, respectively.

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2.2. Preparation of PPI

The alkaline extraction and acid precipitation method described by Kim, Kim, and Nam (1992) was used to prepare PPI. The defatted peanut flour was mixed with distilled water in the ratio of 1:10, adjusting the pH to 9.0 with 1 N NaOH, and stirred at 40 °C in a water bath for 1 h with the stirring speed of 100 rpm. After the extraction process, the suspended material was filtered through a 100-mesh standard sieve. The sediment was centrifuged at 10,000 rpm for 30 min. The resulting supernatant was adjusted to pH 4.5 with 1 N HCl and centrifuged at 4000 rpm for 15 min. The precipitates were then washed with distilled water and centrifuged several times at 4000 rpm for 15 min until a pH of 7.0 was reached. PPI was then dried at 40 °C for 48 h in an air oven, ground to pass through 100-mesh standard sieve and stored at 4 °C from where samples were drawn for analysis. The result about the composition of PPI in the preliminary experiment showed that the protein, fat and crude fiber and carbohydrate contents of PPI were 90.8%, 0.4%, 0.9% and 7.9%, respectively.

2.3. Formulation of PS/PPI blends

PS and PPI were mixed at different ratios (100:0, 90:10, 80:20, 70:30, 60:40 and 50:50) using a mixer (Vortex. Genie2, Scientific Industries, American).

2.4. Water absorption capacity, solubility and swelling power

Water absorption capacity (WAC), swelling power (SP) and solubility were determined at 60 °C, 70 °C, 80 °C and 90 °C, using the method of Sathe and Salunkhe (1981) with the following modifications: 40 mL of a 1% sample suspension (by mass per volume) were prepared in a 50 mL centrifuge tube. A magnetic agitator was placed in the tube, and the suspension was kept at a constant temperature (60 °C, 70 °C, 80 °C or 90 °C) in a water bath for 30 min. The suspension was centrifuged at 4000 rpm for 15 min, then the supernatant was decanted and the swollen granules were weighed. A 10 mL sample was taken from the supernatant, placed in a Petri dish and dried in an air oven at 120 °C for 4 h to reach constant mass. WAC, solubility and SP were calculated using the following equation:

$$\text{water absorption capacity} = \frac{\text{mass of swollen granules}}{\text{sample mass}};$$

$$\text{solubility} = \frac{\text{dry mass} \times 400/\text{sample mass}}{\%};$$

$$\text{swelling power} = \frac{\text{mass of swollen granules} \times 100}{\text{sample mass} \times (100 - \text{solubility})}.$$

2.5. Pasting properties of the PS/PPI blends and the dilute PS sample

The pasting properties of PS/PPI blends were evaluated with a Rapid Visco Analyser (RVA-4, Newport Scientific, Warriewood, Australia) as described by Singh, Sodhi, and Singh (2009). The sample of PS/PPI mixtures (3.0 g, 14%, mb) was weighed directly in the aluminum RVA sample canister, and 25 ml distilled water was added. The sample of dilute PS (100%, 90%, 80%, 70%, 60% and 50%) was weighed on the dry basis of native PS (3.0 g, 14%, mb) in the aluminum RVA sample canister. A programmed heating and cooling cycle was used where the samples were held at 50 °C for 1 min, heated to 95 °C in 3.7 min (heating and cooling rate 12 °C/min), held at 95 °C for 2.5 min before cooling to 50 °C in 3.8 min, and finally held at 50 °C for 2 min. Parameters recorded were pasting temperature (PT); peak viscosity (PV); hot paste viscosity (HPV) (minimum viscosity at 95 °C); cool paste viscosity (CPV) (final viscosity at 50 °C); breakdown (BD) (=PV – HPV); and set back (SB) (=CPV – HPV). All measurements were replicated three times.

2.6. Gel texture properties

The PS/PPI blends formed in the canisters (37-mm diameter, 65-mm height) after RVA testing were covered and kept at 4 °C overnight and allowed to gel. The gel textural analysis was performed by using TA/XT2 Texture Analyzer (Stable Micro Systems, Surrey, England) as described by Bhattachary, Zee, and Corke (1999). The gels were punched to a distance of 10 mm by using a flat cylindrical probe (5-mm diameter.) at a cross-head speed of 1 mm/s. The peak force obtained during this punching was recorded as gel hardness. Two repeated measurements were performed for each sample.

2.7. Scanning electron microscopy (SEM)

The structure changes of CS/SPC blends were observed by using SEM (ABT-150, Topon Corp., Japan) as described by Li, Ye, and Fan (2007). Samples (80% water content) were cooked in boiling water for 20 min then freeze-dried to reach moisture content lower than 5% and broken to expose the cross-section area. These were attached to an SEM stub by using double-backed cellophane tape. The stub and sample were coated with gold-palladium and the cross-section areas were examined and photographed.

2.8. Statistical analysis

All the data obtained were average values of triplicate determinations and subjected to statistical analysis of variance (ANOVA). Least significant differences ($P < 0.05$) were accepted among the treatments.

3. Results and discussion

3.1. Water absorption capacity, swelling power and solubility

The water absorption capacity, solubility and swelling power of PS-PPI blends are presented in Fig. 1. The WAC, solubility and SP values of the blends increased with increase in temperature.

The solubility of the PS/PPI blends was increased as the PPI content was increased from 0 to 50% in the blend. The solubility of the native pea starch at 60 °C and 90 °C were 0.75% and 16.38%, respectively. However, the solubility of the PS/PPI blend at the ratio of 50:50 at 60 °C and 90 °C increased to 22.28% and 31.28%, respectively. The increase in solubility may be due to the effect of the ionic bonds in PPI. Erkan and Sueda (2007) reported that PPI contained many ionic bonds and can influence solubility. When the ratio of PPI in blends increased, PPI occupied more and more dominated position which resulted in higher solubility.

Loos, Hood, and Graham (1981) suggested that swelling power reflected the water absorption index during the granules heating process. Therefore, as the ratio of PPI in blends increased, both WAC and SP increased at 60 °C and decreased at 90 °C. PPI had the typical water absorption feature while PS absorbed little water at 60 °C below the pasting temperature, thus caused slight increases in WAC and SP. The decrease of WAC at 90 °C with increasing proportion of PPI in the blend may be partly due to higher availability of hydrophobic bonds in PPI. Basha and Cherry (1976) reported that water binding of isolated peanut protein may be inversely related to the content of amide nitrogen. Kim et al. (1992) found that the content of acidic and basic amino acids of peanut protein isolate was 32% and 16%, respectively, both of

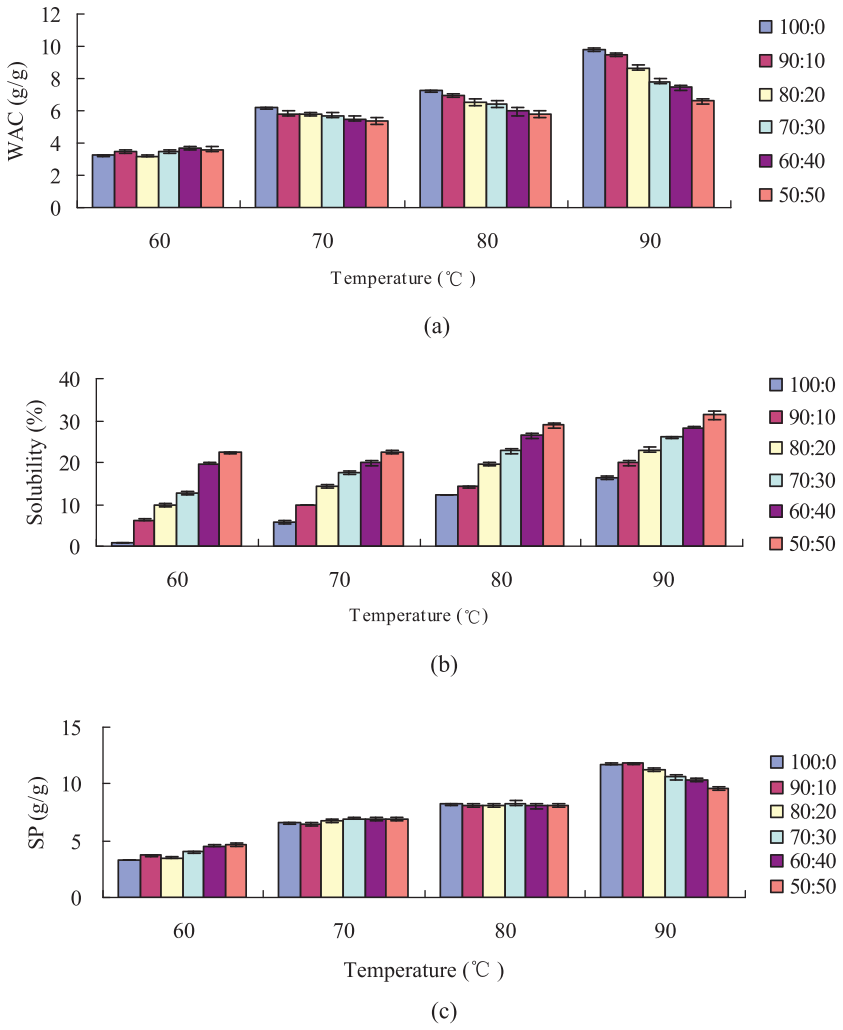

Fig. 1. Water absorption capacity, solubility and swelling power of PS/PPI blends and native PS. PS: pea starch; PPI: peanut protein isolate; 100:0, 90:10, 80:20, 70:30, 60:40 and 50:50 means the individual ratio on dry base of pea starch and peanut protein isolate; (a) water absorption capacity of PS/PPI blends and native PS; (b) solubility of PS/PPI blends and native PS; (c) swelling power of PS/PPI blends and native PS.

which hindered moisture absorption. The decrease in swelling power may be due to the denaturation of PPI caused by high temperature which inhibited the granular swelling behavior. Chinma, Ariahu, and Abu (2011) found a similar trend of results as reported in this study for water absorption capacity, swelling power and solubility when soy protein concentrate was substituted for cassava starch. This phenomenon could be attributed to the decrease in amylose content since amylose acts as a dilutor and swelling inhibitor.

3.2. Pasting properties of PS/PPI mixtures

The pasting properties of PS/PPI blends are shown in Table 1 and Fig. 2. All of the pasting parameters except for the pasting temperature showed a decreasing trend upon increasing ratio of peanut protein isolate in PS/PPI blends. The pasting temperature significantly increased from 72.5 °C to 77.5 °C and the peak viscosity, final viscosity, breakdown and setback significantly decreased from 276.33 to 39.92 RVU, 396.08 to 47.75 RVU, 82.92 to 0.38 RVU and 202.58 to 8.21 RVU, respectively. According to Adebowale, Sanni, and Awonorin (2005), pasting temperature is related to water binding capacity. The higher pasting temperature of PS/PPI blends in this study may be due to their lower water absorption capacity as shown in Fig. 1, which inhibited granule swelling.

A number of factors can significantly affect starch viscosity, including the presence of proteins and protein type. Funami et al. (2008) found that viscosity was due to associations between leached starch molecules (primarily amylose). In this study, PS starch was replaced with PPI in different ratios, which resulted in the decrease of amylose contents. With increasing proportions of PPI in PS/PPI blends, the lower amylose content resulted in the smaller degree of swelling power, which further resulted in the decrease of starch peak viscosity. The same result was achieved by Goel, Singhal, and Kulkarni (1999), who found that a reduction in peak viscosity was caused through partial replacement of normal maize (corn) starch by casein or casein hydrolysates. Kett et al. (2013) confirmed that paste viscosity of mixtures of the milk proteins and waxy maize starch was dominated by the starch component. Ribotta, Colombo, Leon, and Anon (2007) reported that breakdown values were associated with peak viscosities, which in turn, were related to the degree of swelling of the starch granules during heating. Karim, Norziah, and Seow (2000) suggested that setback was typically used as an indicator of the stability of cooked paste. So the decreases of breakdown and setback may caused by the replacement of PS by PPI with different levels.

To elucidate the decreasing of the pasting parameters was not due to the decreased percentage of starch sample, the pasting properties of decreased PS without PPI incorporation were also measured (Table 2). Comparing Table 1 with Table 2, values of

Table 1
Pasting properties of PS/PPI blends.

PS:PPI	PT (°C)	PV (RVU)	HPV (RVU)	CPV (RVU)	BD (RVU)	SB (RVU)
100:0	72.5 ± 0.3^{d}	276 ± 2^{a}	193 ± 1^{a}	396 ± 8^{a}	82.9 ± 3.2^{a}	203 ± 9^{a}
90:10	72.7 ± 0.1^{d}	211 ± 2^{b}	154 ± 1^{b}	284 ± 4^{b}	57.1 ± 1.6^{b}	130 ± 3^{b}
80:20	73.6 ± 0.1^{c}	152 ± 1^{c}	118 ± 1^{c}	193 ± 2^{c}	33.4 ± 0.2^{c}	74.5 ± 0.9^{c}
70:30	74.4 ± 0.6^{b}	102 ± 1^{d}	88.1 ± 0.5^{d}	131 ± 1^{d}	14.2 ± 0.0^{d}	42.8 ± 0.7^{d}
60:40	75.0 ± 0.4^{b}	66.4 ± 0.7^{e}	64.1 ± 0.4^{e}	83.3 ± 1.3^{e}	2.3 ± 0.3^{e}	19.2 ± 0.9^{e}
50:50	77.1 ± 0.2^{a}	39.9 ± 0.2^{f}	39.5 ± 0.2^{f}	47.8 ± 0.0^{f}	0.4 ± 0.1^{f}	8.2 ± 0.2^{f}

PS: pea starch; PPI: peanut protein isolate; PT: pasting temperature; HPV: hot paste viscosity; CPV: cool paste viscosity; BD: breakdown; SB: setback; 100:0, 90:10, 80:20, 70:30, 60:40 and 50:50 means the individual ratio on dry base of pea starch and peanut protein isolate.
Different letters as superscripts (a, b, c, d, e or f) in the same column indicate significant differences ($P < 0.05$).

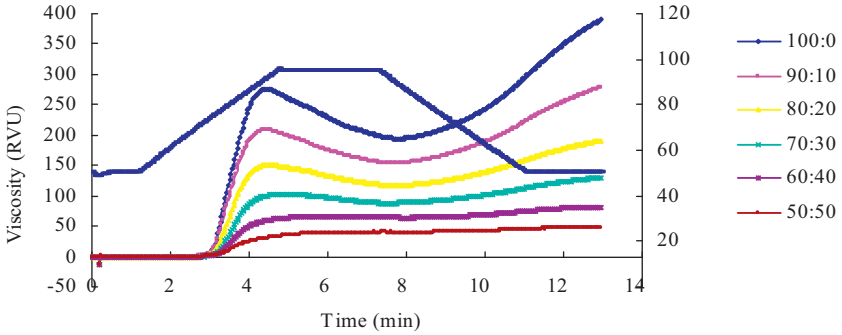

Fig. 2. Pasting profiles of pea starch and peanut protein isolate blends. PS: pea starch; PPI: peanut protein isolate; 100:0, 90:10, 80:20, 70:30, 60:40 and 50:50 means the individual ratio on dry base of pea starch and peanut protein isolate.

Table 2
Pasting properties of dilute PS without PPI addition.

Dilute PS (%)	PT (°C)	PV (RVU)	HPV (RVU)	CPV (RVU)	BD (RVU)	SB (RVU)
100	72.5 ± 0.3^{d}	276 ± 2^{a}	193 ± 1^{a}	396 ± 8^{a}	82.9 ± 3.2^{a}	203 ± 9^{a}
90	72.3 ± 0.1^{d}	191 ± 2^{b}	151 ± 2^{b}	260 ± 1^{b}	39.7 ± 0.2^{b}	109 ± 0.6^{b}
80	73.1 ± 0.1^{c}	126 ± 1^{c}	114 ± 1^{c}	172 ± 3^{c}	11.7 ± 0.2^{c}	57.9 ± 1.5^{c}
70	74.6 ± 0.0^{b}	78.5 ± 0.7^{d}	76.3 ± 0.5^{d}	105 ± 0^{d}	2.3 ± 0.1^{d}	28.3 ± 0.3^{d}
60	76.2 ± 0.3^{a}	46.1 ± 0.4^{e}	46.0 ± 0.4^{e}	59.0 ± 0.8^{e}	0.2 ± 0.0^{e}	13.1 ± 0.4^{e}
50	–	21.7 ± 0.9^{f}	21.5 ± 0.8^{f}	28.0 ± 0.8^{f}	0.2 ± 0.0^{f}	6.5 ± 0.0^{f}

PS: pea starch; dilute PS (100%, 90%, 80%, 70%, 60% and 50%) was weighed on the dry basis of 3.0 g native PS without PPI addition.
Different letters as superscripts (a, b, c, d, e or f) in the same column indicate significant differences ($P < 0.05$).

pasting parameters between PS/PPI blends and decreased PS had significant differences, confirming the change of pasting properties was attributed to the interaction of the filled protein.

3.3. Textural properties of PS/PPI blends gel

Textural properties of PS/PPI blends gel are shown in Table 3. The hardness and gumminess of PS/PPI blends gel decreased with the increasing ratio of PPI. The hardness of native pea starch gel was 9.67 N, which decreased significantly to 0.96 N when the ratio of PS/PPI blends reached 1:1. This phenomenon may be due to the decreased amylose content caused by adding a greater ratio of PPI resulting in lower hardness. Miles, Morris, Orford, and Ring (1985) reported that amylose was the main factor in the short-term development of gel structure. Mua and Jackson (1997) suggested that starches that exhibited harder gels tended to have higher amylose content.

Table 3
Textural properties of PS/PPI blends gel.

PS:PPI	Hardness/N	Springiness	Cohesiveness	Gumminess
100:0	9.67 ± 0.52^{a}	0.99 ± 0.01^{a}	0.50 ± 0.05^{a}	4.83 ± 0.03^{a}
90:10	7.24 ± 0.33^{b}	0.98 ± 0.01^{a}	0.51 ± 0.05^{a}	3.69 ± 0.02^{b}
80:20	5.84 ± 0.16^{c}	0.99 ± 0.01^{a}	0.52 ± 0.04^{a}	3.04 ± 0.01^{c}
70:30	3.85 ± 0.25^{d}	0.96 ± 0.04^{b}	0.42 ± 0.01^{a}	1.62 ± 0.01^{d}
60:40	2.35 ± 0.14^{e}	0.94 ± 0.03^{c}	0.45 ± 0.01^{a}	1.06 ± 0.01^{e}
50:50	0.96 ± 0.04^{f}	0.82 ± 0.06^{d}	0.40 ± 0.01^{b}	0.38 ± 0.00^{f}

PS: pea starch; PPI: peanut protein isolate; 100:0, 90:10, 80:20, 70:30, 60:40 and 50:50 means the individual ratio on dry base of pea starch and peanut protein isolate.
Different letters as superscripts (a, b, c, d, e or f) in the same column indicate significant differences ($P < 0.05$).

The springiness decreased beyond 20% addition of PPI and the cohesiveness decreased significantly with 50% level of PPI. The decreases may be attributed to higher plasticity of PS gel after PPI addition. Bourne (2002) reported that springiness and cohesiveness were indicators of how well the sample can retain its structure after the first compression. Roopa and Bhattacharya (2008) found that wheat and corn gels showed low cohesiveness (0.469 and 0.500, respectively), indicating high plasticity of gels. Bourne (2002) also reported that gumminess was a characteristic of semi-solid foods and was calculated as hardness × cohesiveness. Gumminess decreased progressively as the PPI level increased since both hardness and cohesiveness of PS gels decreased in this study. This result was in line with Pietrasik (1999) who reported that low gel gumminess could be achieved by adding plant proteins.

3.4. SEM images of PS/PPI blends gel

The morphology of PS/PPI blends is shown in Fig. 3. Both native PS and PS/PPI blends formed three-dimensional network

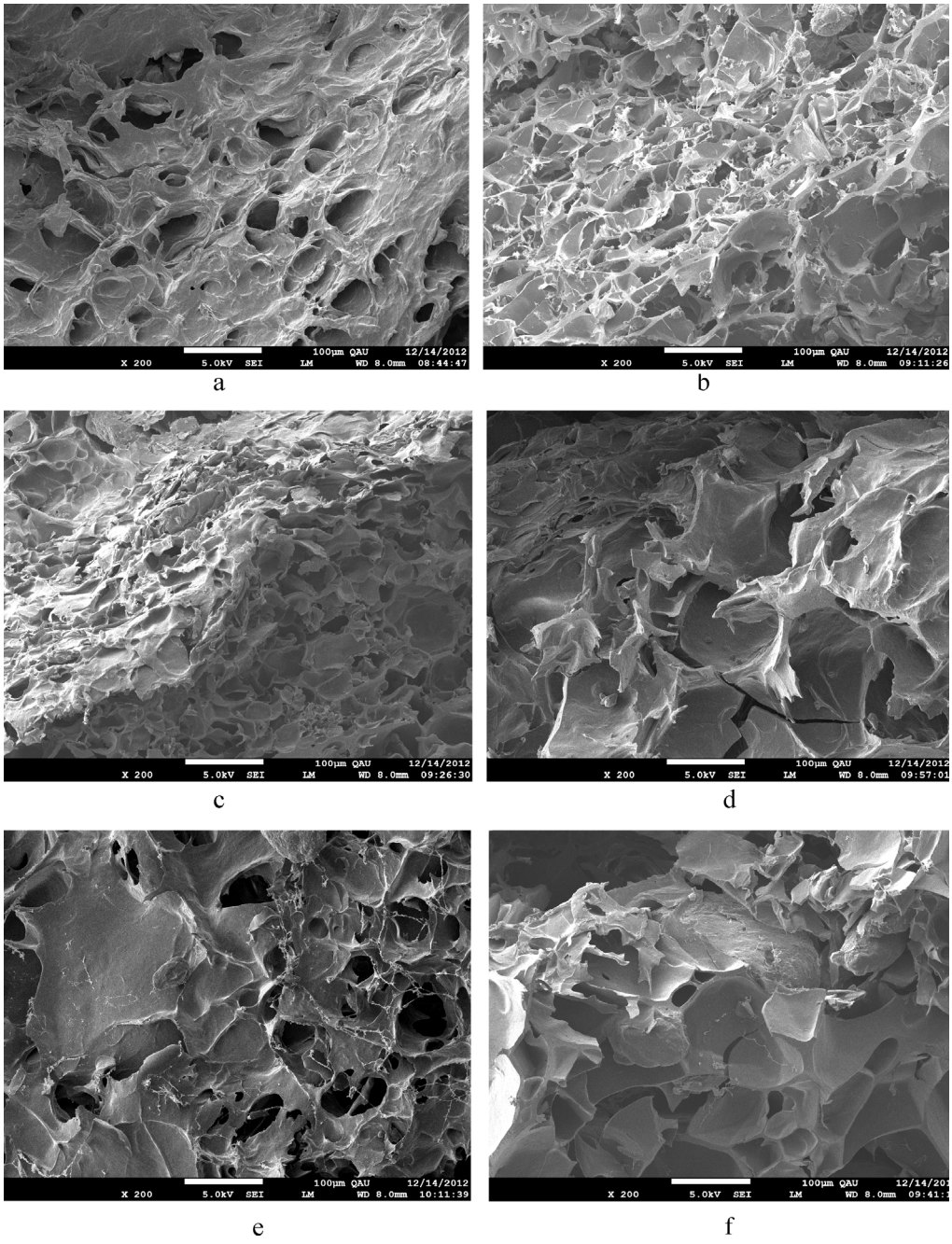

Fig. 3. SEM images of PS/PPI blends gel. Images of a–f stand for the gel image of PS, PS:PPI = 90:10, PS:PPI = 80:20, PS:PPI = 70:30, PS:PPI = 60:40, and PS:PPI = 50:50, respectively.

after being cooked in boiling water for 20 min. However, the three-dimensional network of PS/PPI blends (Fig. 3b–e) appreciably differed from the microstructure of native heat-induced PS gel (Fig. 3a). The native PS gel without PPI showed a relatively dense and compact structure with some pores. The PS/PPI blends gels at the ratio of 90:10 and 80:20 exhibited more pores and showed a honeycomb feature which indicated that PPI molecules can interact and modulate the structure of PS gel, forming a more interactive gel network. Sun, Xu, and Li (2012) reported that the addition of PPI improved and modified the microstructure of heat-induced salt-soluble protein (SSP) gels as the network of SSP gel was loose with large, irregular holes and exhibited an aggregation-type and slightly porous protein matrix; whereas a more uniform, compact and homogeneous structure was observed from SSP when PPI was incorporated. The PS/PPI blend gels at the ratio of 70:30 showed a large fragmentary structure. When the ratio of PPI in PS/PPI blends continually increased, gel structure of PS/PPI blends (Fig. 3e and f) became more and more loose and noncompact. This may be due to poor congealing ability of PPI. As reported by Kato (1996), most of the proteins showed rigid structure which may suppress the formation of conjugates. Above all, filament appeared on the surface of all PS/PPI blends with different ratios of PPI, which indicated that PPI could be attached to the surface of PS gel.

4. Conclusions

The blends of PS/PPI of different compositions, 100:0, 90:10, 80:20, 70:30, 60:40 and 50:50, may have different functional and pasting properties. The water absorption capacity and swelling power of PS/PPI blends decreased upon increasing incorporation

of PPI, indicating that PS/PPI blended edible films may have better water resistance than pure PS films. The breakdown and setback of gels decreased, suggesting good stability of cooked paste. The hardness and cohesiveness of PS/PPI blends gel decreased, especially when the ratio of PS/PPI reached 50:50, which can improve the gel plasticity. SEM showed three-dimensional network of PS/PPI blends differed from the microstructure of native heat-induced PS gel. The PS/PPI blend gels at the ratio of 90:10 and 80:20 exhibited a honeycomb feature, and the structure of PS/PPI blend gels became more loosed when the ratio of PPI in PS/PPI blends increased. Such data may be useful for PS and PPI food formulations as well as in edible film preparations.

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