Effect of high pressure and soy protein isolate combinations on the water holding capacity and texture of pork meat batters

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Abstract

Introduction. The used of high pressure and soy protein isolate combinations to emulsion meat products could improve the quality, water holding capacity, texture and increase product yield.

Materials and methods. Raw pork batters were prepared as follows: 400g pork meat, 80g pork back-fat, 70g ice water,10g NaCl; sample C2 had 10g soy protein isolate (2%); sample C3 - 20g soy protein isolate (4%). The vacuum packed batters were put into a high pressure vessel and were done with 200 MPa for 10 min at 10±2° C. The texture profile analysis of cooked pork batters were carried out using a texture analyzer. Low field NMR relaxation measurements were carried out according in the NMR probe of a Niumag Pulsed NMR analyzer.

Results and discussion. Compared with the C1, all the cooking yield of pork batters with various amount of soy protein isolate were increased significantly. The emulsifying activity of 11S globulins was much significantly improved at 200 MPa, that enhanced the water holding capacity of soy protein isolate. High pressure processing induced texture modifications have been used to affect myofibrillar proteins and their gel-forming properties, raising the possibility of the development of processed comminuted meat products. Over 200 MPa treatment, the protein extractability was decreased significantly in meat batters, and caused protein denaturation and/or aggregation, which limited their functionalities. The effects of relaxation time and peak ration of cooked pork batters by high pressure processing with different soy protein isolate were determined. There was three characteristic peaks in the cooked pork batters, which was named as T_{2b}, T_{21} and T_{22}, respectively. T_{2b} is assigned to water tightly associated to protein and macro-molecular constituents, the relaxation population centered at approximately 0-10 ms in the cooked pork batters. The relaxation population of T_{21} is centered at approximately 10–100 ms, which is a major component and considered to intra-myofibrillar water and water within the protein structure.

Conclusion. The result of low field NMR exhibited that the batters with soy protein isolate had less water out the cooked pork batter and free water. Overall, the 2% soy protein isolate addition could improve the water holding capacity and texture of pork batters treated by high pressure.

Introduction

The application of high pressure processing to modify the properties of meat and soy proteins, increase the water holding capacity and texture of cooked meat and soy proteins products. The used of high pressure and soy protein isolate combinations to emulsion meat products could improve the quality and lower the salt and fat content in the meat industry.

High pressure is a non-thermal technology that has been successfully applied to several meat products, and the applications of high pressure in food industry continue growing recently years [1,2]. The functions of high pressure in meat products contain the inactivation of microorganism and enzymes with minimal effects on flavor, color and nutritional quality [3-5]. Study [6] authors observed an increase in water holding capacity due to the interaction of high pressure processing and salt in pork meat batter, this may be because increasing sodium chloride causes increasing denaturation of muscle proteins in high pressure treated meat batters and favors the solubilization of proteins and the formation of a gel network that retains water and fat. Study [7] authors found that the textural properties of hardness, chewiness, springiness, cohesiveness and resilience were significantly ($P < 0.05$) increased at an interval of 100 MPa and 200 MPa, except the textural property of adhesiveness up to 200 MPa, but no changes of of hardness, chewiness, springiness and resilience were observed up to 300 MPa and 400 MPa. Study [8] authors showed that free SH content of soy protein isolate was significantly ($P < 0.05$) increased after high pressure treatment at 200 MPa. However, it is important to study the effect of high pressure processing on the food components, mainly proteins in the meat and soy to optimize the processing parameters to get high-quality products [9,10]. Soy protein isolate is a commonly useful vegetable protein in the meat industry, which has a good water and fat holding capacity, excellent gelling and structuring behaviour [11,12]. Some researchers have reported that added the soy protein isolate to meat batters could improve the water holding capacity, texture and nutritional quality. But few papers reported the effect of high pressure and soy protein isolate combinations on property of pork meat batter.

Therefore, the objective of the present study was to determine the water holding capacity and texture differences of pork meat batter which were produced by high pressure with soy protein isolate, and thereby to establish a method to obtain pork meat batter with desirable quality.

Materials and methods

Raw materials and ingredients

The *longissimus dorsi* of chilled pork (Moisture, 71.35±0.52%; protein, 22.57±0.37%; fat; 2.83±0.26%; pH, 5.63±0.02) were derived from the landrace (100±5 kg) which were slaughtered at the age of about 6 months provided by the Gaojin Group (China), and the temperature after slaughter 24 h was 2~4 °C. After removing of the visible connective tissue and fat, the pork meat was minced using a meat chopper with a 6 mm holes plate (MGB-120, Shandong Jiaxin Food Machinery Co., Ltd., China). Pork back-fat (90.21±0.56% fat) was purchased from a local meat market (Xinxiang, China), and also was minced using a meat chopper with a 6 mm holes plate. Soy protein isolate (91.32±0.83% protein) was provided by Shandong Soy Foods co., Ltd (China).

Prepared pork batters

Raw pork batters were prepared as follows: C1, 400g pork meat, 80g pork back-fat, 70g ice water,10g NaCl; C2, 400g pork meat, 80g pork back-fat, 70g ice water,10g NaCl, 10g soy protein isolate (2%); C3, 400g pork meat, 80g pork back-fat, 70g ice water,10g NaCl, 20g soy protein isolate (4%). The pork batters were produced by a bowl chopper (Stephan UMC-5C, Germany). Briefly, the 400 g pork meat was placed into the bowl chopper with 20 g NaCl. The mixture was chopped for 30s with 1/3 ice water, then the 80g pork back-fat, 10g/20g soy protein isolate 1/3 ice water was added and the chopping was continued for 30s. Finally, the remaining ice water was added and chopped for 60s. During the chopping processing, the meat batters were maintained at a temperature below 8 °C. The raw pork batters were then stuffed into 24 mm diameter polyamide casings (Xianyi casing Co., Ltd., Henan, China) using a sausage stuffer machine (Xiaojin Machinery Co., Ltd., Hebei Shijiazhuang, China) and linked every 160 mm. Finally, the batters were vacuum packed for subsequent pressure processing.

High pressure treatment

High pressure treatments of sausage batters were carried out in a 0.3 L capacity high pressure vessel (S-FL-850-9-W/FPG5620YHL, Stansted Fluid Power Ltd., Stansted, UK) which has a maximum pressure limit of 900 MPa and can work in the temperature range of -20ºC to +90ºC with a thermo-stated jacket (Figure 1). Product canister: 260mm internal usable height with demountable thermacouple, 37mm internal usable diameter [13].

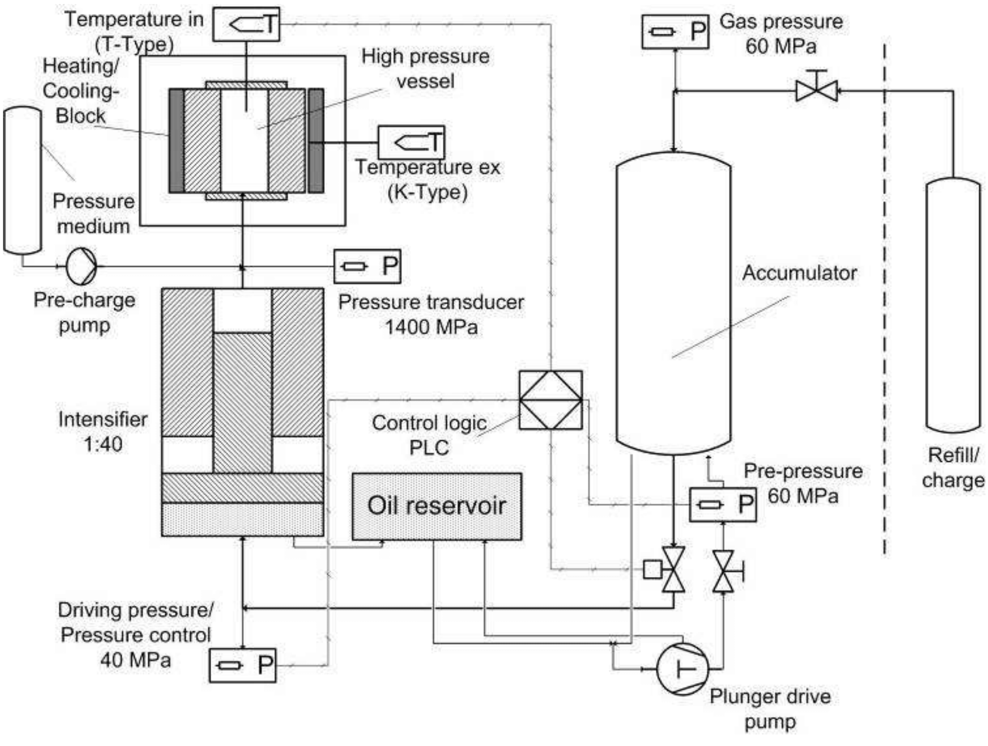

Figure 1. Schematic diagram High pressure vessel with heating cooling system (S-FL-850-9-W/FPG5620YHL, Stansted Fluid Power Ltd., Stansted, UK) [13]

The pressure transmitting medium used was water and was previously adjusted to the desired temperatures with circulating water from a thermo-stating circulator bath (ILB-WCS, STIK Shanghai Co., Ltd.). The temperature of the pressure medium was monitored during processing by a T-type thermocouple fixed inside the vessel. The temperature was maintained by circulation of the temperature controlled fluid through. The compression and decompression took place over a period of 42 s and 25 s respectively. The time spent on loading and unloading sample was approximately 1 min.

All samples were heated in a water bath (TW20, JULABO Technology Co. Ltd., Seelbach, Germany) at ambient pressure (0.1 MPa) if not specified.

The pork batters were done with 200 MPa for 10 min at 10±2 °C. All samples were heated in a water bath (HH-42, Changzhou Guohua Electrical Appliance Co., Ltd., China) at 80 °C for 30 min (internal temperature 72 °C), then cooled immediately with running water and stored at 4 °C for analysis.

Determination of cooking yield

The cooking yield of pork batters was calculated according to the following formula [14]:

$$\text{Cooking yield (\%)} = \text{cooked meat batter/raw meat batter} \times 100\%$$

Each measurement was replicated 5 times.

Water holding capacity

The water holding capacity of the samples was measured according to the method of [15]. Sample with casing was weighed (weightsample). After removing the casing from the sample, the surface water of the product was absorbed using filter paper and reweighed ($weight_{product}$). The empty casing was dried and weighed ($weight_{casing}$). Released water was expressed as a percentage of the original weight.

$$\text{Released water (\%)} = (weight_{sample} - weight_{product} - weight_{casing})/(weight_{sample} - weight_{casing}) \times 100$$

Determination of texture

Samples were assessed for texture profile analysis (TPA) according to the procedure of [16-18], using a texture analyzer TA-XT plus (Stable Micro Systems Ltd., UK) with an aluminum cylindrical probe P/36R at ambient temperature (20 - 25^{o}C). The indicators of hardness, springiness, cohesiveness and chewiness were determined. Each measurement was replicated 5 times.

Parameters as follow: pre-test speed 2 mm/s, test speed 2 mm/s, post-test speed 2 mm/s, compression ratio 40 %, trigger force 5 g, and 5 s was allowed between the two compression cycles.

The texture profile analysis of cooked pork batters (the cylindrical-shaped with a diameter of 20 mm and a height of 20 mm) were carried out using a texture analyzer (TA-XT plus Texture analyzer, Stable Micro Systems, UK) with an aluminum cylindrical probe P/36R.

Cylindrical samples (20 mm diameter; 20 mm height) were axially compressed to 40 % of their original height using a double compression cycle test. The trigger force used for the test was 5 g, with a pretest speed of 2 mm/s, test speed 2 mm/s, post-test speed 2 mm/s. A time of 5s was allowed to elapse between the two compression cycles. The data were generated by Exponent software (Exponent stable microsystem, version 5.1.2.0, Stable Microsystems Ltd., UK) provided with the instrument (Figure 2). Attributes of hardness, springiness, cohesiveness, chewiness and resilience were determined. Each measurement was replicated 5 times.

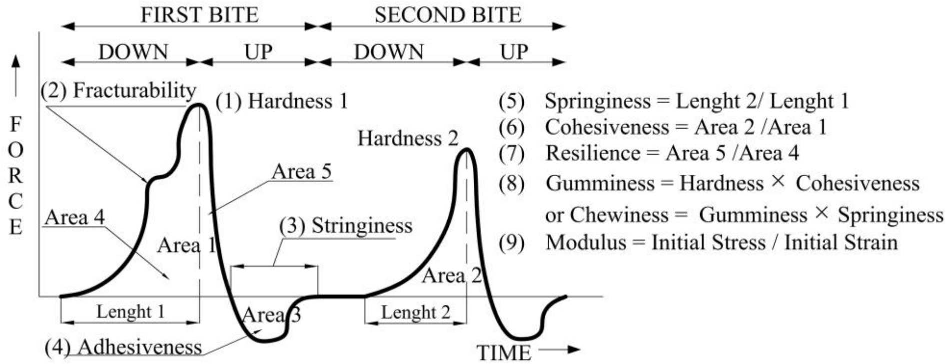

Figure 2. The parameter definition interpretation of qualitative curve analytical method [16]

Hardness. It is the biggest peak of compression for the first time.

Springiness. The quotient or volume ratio of the compressed deformed sample to the predeformed condition after removing the deforming force. Elasticity is expressed by the ratio (Length2/ Length1) of the specimen recovery height (Length 2) measured in the second compression to the first compression deformation (Length 1).

Cohesivenes*s*. The relative resistance of the test sample to the second compression after the first compression deformation is shown in the curve as the ratio of positive work (Area 2/Area 1) of the two compressions. This value represents the total work required to overcome the attraction between the two surfaces when the probe comes into contact with the sample.

Chewiness. It is only used to describe the test sample in solid state, indicating the energy required to chew the solid sample into a stable state when swallowing. The numerical value is expressed by the product of the stickiness and elasticity (hardness x cohesive elasticity).

Low field NMR measurements

Low field NMR relaxation measurements were carried out according to the method of [19, 32]. About 2 g of the cooked pork batter was placed in a 15 mm glass tube and inserted in the NMR probe of a Niumag Pulsed NMR analyzer (PQ001, Niumag Electric Corporation, Shanghai, China).

Spin-spin relaxation time (T_2) was measured made a τ-value of 350 μs by the Carr–Purcell–Meiboom–Gill sequence at resonance frequency of 22.6 MHz, 32 °C. Post processing of T2 data distributed exponential fitting of Carr-Purcell-Meiboom-Gill decay curves were performed by Multi-Exp Inv Analysis software (Niumag Electric Corp., Shanghai, China). Each measurement was replicated 4 times.

Statistical analysis

The experiment was four replications. The data was analyzed using the one-way ANOVA program (SPSS v.18.0 for Windows), the difference between means was considered significant at $P < 0.05$.

Results and discussion

Cooking yield

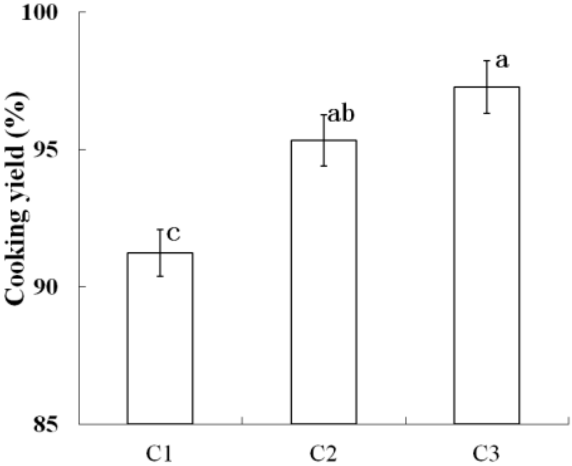

Figure 3. Effect on cooking yield (%) of pork meat batters by high pressure processing with different soy protein isolate:
C1, 0g soy protein isolate; C2: 10g soy protein isolate; C3: 20g soy protein isolate.
Each value represents the mean ± SD, n = 4.
[a-c] Different parameter superscripts in the figure indicate significant differences (p < 0.05)

The effect of high pressure with various amount of soy protein isolate on the cooking yield of pork batters was shown in Figure 3. A higher cooking yield of pork batters reflects a better water holding capacity. Compared with the C1, all the cooking yield of pork batters with various amount of soy protein isolate were increased significantly ($P < 0.05$), but the cooking yields of C1 and C2 were no significantly ($P < 0.05$) differences. The reason might be that added the 2% soy protein isolate could hold the water of pork batters very well, so increased the soy protein isolate addition could not improved the cooking yield. The emulsifying activity of 11S globulins was much significantly improved at 200 MPa, that enhanced the water holding capacity of soy protein isolate [20]. Study [21] authors used of the soy protein isolated, wheat flour (WF), and κ-carrageenan as binder, showed that the addition of binders improved water-binding properties of pressure or non-pressure-induced restructured pork. The similar result was reported by [22], who used the dried egg white as fat replacement to obtain a low-fat chicken gel by means of high pressure, the water binding properties and hardness were improved, suggested their participation in the network structure coupled to the myofibrillar proteins, and noted that the modifying certain functional characteristics of chicken meat gels with low fat content by means of high pressure and the addition of dried egg white. Thus, the addition of soy protein isolate could improve the cooking yield of pork batters.

Texture

Table 1

Texture of cooked pork batters by high pressure processing with different soy protein isolate

Sample	Hardness (N)	Springiness	Cohesiveness	Chewiness (N mm)
C1	47.32±1.12^{c}	0.837±0.008^{b}	0.641±0.005^{c}	27.05±0.85^{c}
C2	53.21±0.98^{a}	0.863±0.009^{a}	0.687±0.007^{a}	35.68±0.89^{a}
C3	50.42±1.05^{b}	0.835±0.007^{b}	0.655±0.008^{b}	29.67±0.96^{b}

C1, 0g soy protein isolate; C2: 10g soy protein isolate; C3: 20g soy protein isolate.
Each value represents the mean ± SD, n = 4.
$^{a\text{-}c}$ Different parameter superscripts in the figure indicate significant differences ($p < 0.05$).

The texture of cooked pork batters were affected significant ($P < 0.05$) by high pressure and soy protein isolate combinations (Table 1). Compared with the C1, all the hardness, springiness, cohesiveness and chewiness of pork batters with various amount of soy protein isolate were increased significantly ($P < 0.05$), except the springiness of C3. Compared with the 4% (C3), the hardness, springiness, cohesiveness and chewiness of pork cooked batter with 2% soy protein isolate (C2) were significantly increased ($P < 0.05$). High pressure processing induced texture modifications have been used to affect myofibrillar proteins and their gel-forming properties, raising the possibility of the development of processed comminuted meat products. Over 200 MPa treatment, the protein extractability was decreased significantly in meat batters, and caused protein denaturation and/or aggregation, which limited their functionalities [23,24]. Although the soy protein isolate have has a good water and fat holding capacity, excellent gelling and structuring behaviour, some paper have reported that excessive added the soy protein isolate could lower the texture of meat batters [21]. Therefore, the pork cooked batter with 2% soy protein isolate (C2) had the best texture.

Low field NMR

The effects of relaxation time and peak ration of cooked pork batters by high pressure processing with different soy protein isolate were determined (Table 2). There was three characteristic peaks in the cooked pork batters, which was named as T_{2b}, T_{21} and T_{22}, respectively. T_{2b} is assigned to water tightly associated to protein and macro-molecular constituents, the relaxation population centered at approximately 0-10 ms in the cooked pork batters 25[19]. The relaxation population of T_{21} is centered at approximately 10-100 ms, which is a major component and considered to intra-myofibrillar water and water within the protein structure. T_{22} is corresponds to extra-myofibrillar water and centered at approximately100-400 ms [26,27] Compared with the C1, the initial relaxation times of T_{2b}, T_{21} and T_{22} were quicker ($p < 0.05$) in the C2 and C3, the result indicated that the cooked pork batters made with various amounts of soy protein isolate were bound tightly, because the changes of fast relaxing protein and slowly relaxing water protons [28,29].

These also were accordance with the changes of texture and cooking yield (Table 1 and Figure 3). The reason was possible that the soy protein isolate had excellent gelling and structuring behaviour, then a better gel structure of cooked pork batters by high pressure processing was formed when added the soy protein isolate [30]. The emulsifying activity of

11S globulins of soy protein isolate was much significantly improved at 200 MPa, through the changes of protein solubility, surface hydrophobicity, free SH content and secondary structure [20,31]. All the peak rations of T_{2b} were no significant differences ($p > 0.05$), C2 and C3 had the smallest peak rations of T_{22}, and had the largest peak ration of T_{21} (Figure 4).

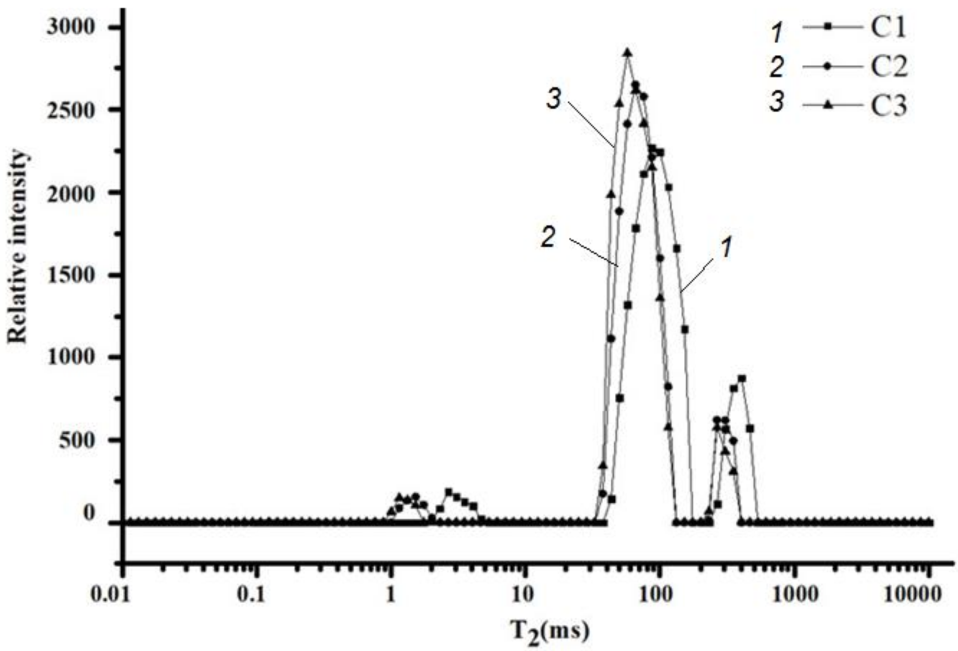

Figure 4. Curves of relaxation time (T2) in cooked pork batters by high pressure processing with 1000 different soy protein isolate

Added the soy protein isolate and high pressure processing combinations could increase the protein content, more meat proteins can become available for gel formation of the meat matrix. These caused the water tightly associated to protein and macromolecular constituents decreased, and improve water holding capacity of cooked meat batters [33]. Therefore, added the soy protein isolate increased the water holding capacity, and improved the texture of cooked meat batters.

Table 2

Relaxation time (ms) and peak ration (%) of cooked pork batters by high pressure processing with different soy protein isolate

Samp-le	Relaxation time (ms)			Peak ration (%)		
	T_{2b}	T_{21}	T_{22}	T_{2b}	T_{21}	T_{22}
C1	1.95±0.13[a]	44.23±1.42[a]	265.51±4.26[a]	1.22±0.15[a]	85.66±2.36[b]	13.26±0.85[a]
C2	1.12±0.15[b]	37.25±1.59[b]	232.87±4.68[b]	0.96±0.12[a]	91.87±2.45[a]	8.31±0.80[b]
C3	1.06±0.11[b]	36.30±1.45[b]	227.52±4.31[b]	1.03±0.12[a]	93.26±2.14[a]	7.03±0.86[b]

C1, 0g soy protein isolate; C2: 10g soy protein isolate; C3: 20g soy protein isolate.
Each value represents the mean ± SD, n = 4.

Conclusion

The effect of high pressure and soy protein isolate combinations on the gel properties of pork batters was significant differences ($P < 0.05$). Compared with the C1, C2 and C3 had a higher cooking yield and hardness, cohesiveness and chewiness. The result of low field NMR exhibited that the batters with soy protein isolate had less water out the cooked pork batter and free water. Thus, C2 had the best water holding capacity and texture. Overall, the 2% soy protein isolate addition could improve the water holding capacity and texture of pork batters treated by high pressure.

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