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Effects of High Pressure Assisted and Shift Freezing Process on the Physical Properties of Pork Muscle

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Introduction

Freezing in food technology is one of the effective preservation methods through changing liquid water to solid ice. However, ice crystals formed during freezing have a great influence on the quality of food stuffs and could result some damages from formation of ice within tissue causing exudates and modification of texture (Martino *et al.*, 1998). This frozen damage largely occurred in phase transition process of water and so phase transition time should be minimized to prevent the degradation of food quality (Park *et al.*, 2005). Therefore, nowadays, high pressure freezing has appeared as a new parameter in food processing for about 10 years which can improve quality of frozen food coupled with decreased phase transition time, homogeneous nucleation and formation of fine ice crystals in food stuff (Martino *et al.*, 1998; Lebail, 2002). In high pressure domain, phase transition point and latent heat of water decreases in Ice I domain. This phenomenon enhances the heat flux rate during freezing and thawing process which increases qualitative aspects of frozen food (Zhu *et al*, 2004). Therefore, this study was conducted to investigate the characteristics of phase transition phenomenon and its' influence on physical properties of pork muscle in high pressure freezing process.

Materials and Methods

Porcine *M. logissimus dorsi* obtained from carcass was stored for 24 hr at 4℃. Samples of cylinder type(30×100mm) were respectively vacuum packed before each freezing experiment. High pressure freezing apparatus that manufactured in our laboratory (Fig. 1) consisted of a high pressure vessel (HPV- I , Hiptec, Busan, Korea), hydrostatic pressure pump (HSF-300, Haskel, California, USA) and cryostat (FP-80, Julabo, Seelbach, Germany). In this research, PSF (pressure shift freezing) was carried out by instant pressure release reaching the central temperature to -9℃ at 100 MPa which is slightly higher than the phase transition point of pork under 100 MPa and then it was subjected to the secondary freezing process for 12 hr in the air freezer of -50℃. Pressure assisted freezing (PAF) was completed after the elapse of freezing plateau under 100 MPa and subjected to secondary freezing for 12 hr in the air freezer of −50℃. In each PSF and PAF process, the temperature of external cooling jacket was set to −50℃. AF (atmospheric freezing) and PBF (pressurization before freezing) were progressed in the air freezer −50 ℃ for 12 hr. In PBF experiment, vacuum packed sample was treated for 30 min at 4℃ under the pressure level of 100 MPa before atmospheric freezing process. After secondary frezing, water immersion thawing was carried out to the central temperature of 4℃ and then physical properties were compared through thawing loss, water holding capacity (WHC), cooking loss, color and pH measurement.

Results and Discussion

1. Freezing Process

Evolution of phase transition point, time and supercooling degree of pork in each freezing process was presented in Table 1 and Fig. 2. In the depression of phase transition point under 100 MPa, our results were fairly in accordance with the calculated phase transition point in pork muscle with regression equation (Eq. 1) proposed by Zhu *et al.* (2005). The maximum degree of supercooling was obtained in PSF process because phase transition point of pork muscle increased to the state of atmospheric pressure after instant release of pressure. Phase transition point and time significantly decreased in PSF and PAF comparing to AF The minimum phase transition time was observed in PAF as 486 s. This result might originate from the decreased latent heat of water in high pressure domain which reduce the energy required for phase transition described in Eq. 2 (Bridgman, 1911).

$$T=-0.89-0.0729 \cdot P-0.000172 \cdot P2 \qquad \text{Eq. 1}$$

$$L=333549.295-399.369 \cdot P-0.388 \cdot P2 \qquad \text{Eq. 2}$$

T· Phase transition point of pork muscle in high pressure domain (℃),

L· Latent heat of water in high pressure domain (J/kg), P: Pressure (MPa)

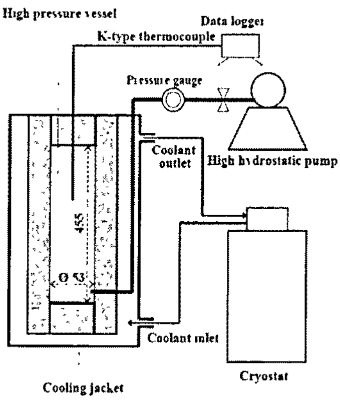

Fig. 1. Schematic diagram of high pressure freezing apparatus.

Table 1. Evolution of phase transition and supercooling due to different freezing process.

	Phase transition point (℃)	Phase transition time (s)	Degree of supercooling (℃)
AF	−1.2	1,262	·
PSF	−1.2	730	9.5
PAF	−10.1	486	3.7
PBF	−1.2	997	·

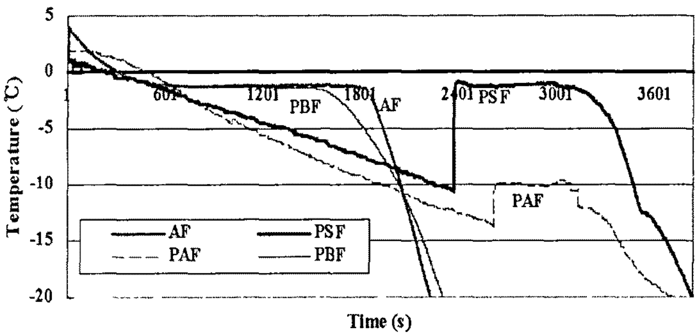

Fig. 2. Temperature evolution of pork muscle in each freezing process.

2. Water Binding Abilities

Water binding abilities expressed with thawing loss, WHC and cooking loss were presented in Table 2. All samples PSF, PAF and PBF represented lower thawing loss than AF and the minimum value was obtained as 1.21% from PAF sample. In the research of Schubring *et al.* (2003), similar results were obtained that meant PAF induced decreased thawing loss in various fish species.

WHC in PSF, PAF and PBF sample showed significantly higher value than that of AF ($P<0.05$). The highest value was observed from PAF sample representing 81.18%. Whereas, cooking loss slightly decreased in all of PSF, PAF and PBF samples comparing to AF. From our experimental results, it is predicted that PSF and PAF had some beneficial

Table 2. Comparison of thawing loss, WHC and cooking loss among experimental conditions

	Thawing loss	WHC	Cooking loss
AF	2.56±0.041[a]	73.05±1.688[b]	33.08±0.897[a]
PSF	2.56±0.456[a]	79.32±0.017[a,b]	31.63±1.571[a]
PAF	1.21±0.670[b]	81.18±6.426[a]	31.21±0.282[a]
PBF	2.17±0.234[a]	77.30±1.418[a,b]	31.79±1.156[a]

influence on the water binding ability of meat comparing to conventional freezing process. Especially, PAF indicated the most superior water binding ability from the results of thawing loss, WHC and cooking loss.

These results might originate from reduced tissue damage influenced by decreased phase transition time in high pressure domain. Martino *et al.* (1998) reported lesser structural damage in pork muscle of PAF comparing to conventional methods such as air-blast and cryogenic fluid freezing. In this increased water binding ability in meat by PAF, further researches are required coupled with phase transition and nucleation phenomena in freezing process under high pressure domain.

3. Color

Table 3 showed the changes in each color value among experimental conditions. All samples of PSF, PAF and PBF indicated significantly different color values comparison with that of AF. These results were summarized as increment of L, a and b value of meat after high pressure freezing or treatment. Generally, it is well known that application of high pressure induces drastic changes in the color of red muscle. This phenomenon appears to result from (1) globin denaturation and/or to heme displacement or release (2) oxidation of ferrous myoglobin to ferric metmyo-globin (Cheftel and Culioli, 1997). More researches are needed about the influence of high pressure on meat color considering that consumers use meat color as purchase criterion.

Table 3. Comparison of each color value among experimental conditions

	L	a	b
AF	53.20±2.33[c]	8.50±1.01[b]	10.55±0.5[c]
PSF	58.80±1.32[b]	10.65±1.32[c]	12.50±0.63[a]
PAF	62.83±2.27[a]	9.88±0.99[a,b]	13.28±1.05[a]
PBF	59.18±1.48[b]	9.60±1.37[a,b]	12.75±0.24[c]

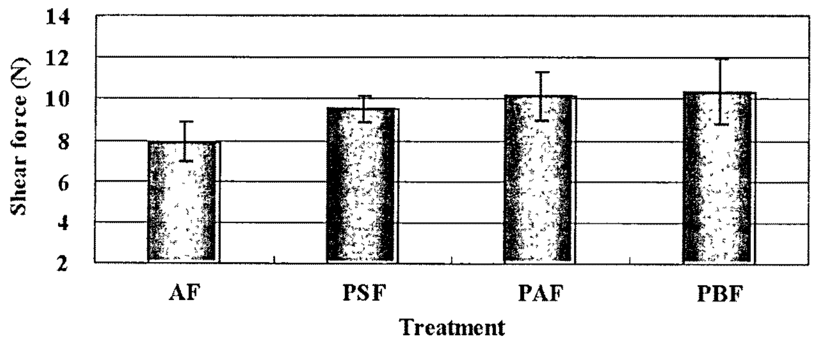

Fig. 3. Changes in shear force among different freezing process.

4. Waner–Blatzler Shear Force

In the textural aspect of meat, influence of different freezing processes on shear force was presented in Fig. 3. All of PSF, PAF and PBF indicated significantly higher value than AF(P<0.05), and so it was impossible to get the tenderization effect of post rigor pork with high pressure freezing in this research. Similar results were obtained in the research of Macfarlane *et al.* (1980) and Yuste *et al.* (1998) that meant the increment of hardness of meat in the low temperature high pressure treatment. This indicates that proteolysis and ultrastructral modifications are not directly and simply linked to meat tenderness (Cheftel and Culioli, 1997). Therefore, it is predicted that freezing process in high pressure domain could not induce the tenderization effect of post rigor meat.

5. pH

Changes in pH of different freezing processes were presented in Fig. 4. All of PSF, PAF and PBF resulted in significantly higher pH than that of AF and the maximum value was obtained as 5.74 in PAF treatment. These results were predicted to originate in the direct effect of high pressure treatment not an influence freezing in high pressure domain from the results of PBF sample. Similar results were found in the research of Ma and Ledward (2004) that meant the increment of pH value in high pressure treated beef muscle and our previous research (Hong *et al.*, 2005). In this regard, further researches are required coupled with protein denaturation and ionization of water ($H^+ \times OH^-$) in high pressure domain.

Summary

In this research, PSF and PBF indicated beneficial influence on water binding ability of meat comparing to conventional freezing methods. High pressure in freezing process resulted some changes inhysical characteristics of pork: increment each color value, shear force and pH in PSF, PAF and PBF.

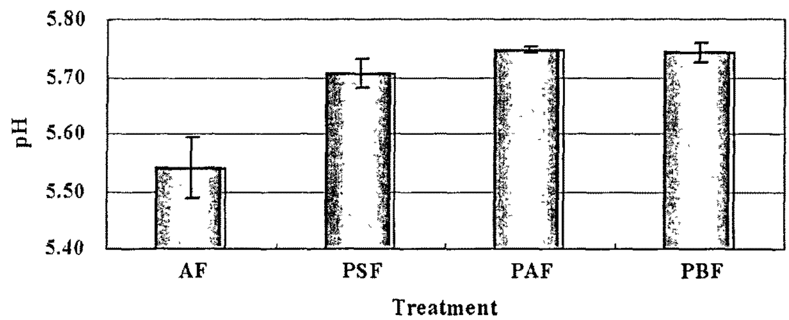

Fig. 4. Changes in pH among different freezing process.

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