HIGH PRESSURE EFFECT ON MYOFIBRIL AND MEAT PATTY OF CHICKEN PECTORAL MUSCLE

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Background

Pressure treatment of meat is expected to develop novel processed meat products. Since myofibril is a fundamental unit of muscle tissue, it is important to know the pressure-induced changes in myofibrils to understand pressure effect on meat. Myofibril retains its architecture at physiological salt concentration and pH, and no solubilization substantially occurs at low ionic strength. When salt is added to myofibrils to a final concentration of approximately 0.3 M, myosin is dissociated from thick filament. Most of myofibrillar proteins are solubilized in 0.5–0.6 M KCl. Besides salt effect on solubilization of myofibrils, pressure treatment is known to induce dissociation of thin [1] and thick filaments [2]. We had reported that myosin filaments formed a gel by pressure application [3] and monomeric myosin in high salt concentration failed to form a gel [4]; however, pressure-induced gelation of myofibrils is not well studied.

Objectives

The present study is aimed to elucidate pressure effect on solubilization and gelation of myofibrils at low ionic strength, in which myofibrillar proteins are not soluble under the atmospheric pressure. In addition, rheological properties of pressurized and heat treated meat patty was investigated.

Methods

Myofibrils were freshly prepared from chicken pectoral muscle. Myofibrils were suspended in 0.1 or 0.2 M NaCl at pH 6.0 or 7.0 for a solubility measurement. After pressure release, the samples were centrifuged, and then the supernatant and the precipitate were collected. Protein concentration in the supernatant was measured, and the protein composition was analyzed by SDS-PAGE. The morphology of unsolubilized myofibrils was observed by phase contrast microscope.

Pressure-induced gel was prepared from myofibrils. A spherical plunger (diameter of 7 mm) was penetrated into a pressure-induced gel with a constant speed of 0.5 mm/sec. A force was recorded during penetration, and the maximum peak force was used as gel strength. We also observed morphology of gel structure by scanning electron microscopy.

Rheological parameters of pressurized and heat treated myofibrils and meat patties were also measured.

Results and discussion

Pressure-induced solubility change of myofibrils at 0.1 M and 0.2 M NaCl is shown in Fig. 1. When the applied pressure was 100 MPa, pressure-induced solubilization was very low regardless of NaCl concentration and pH. With increasing applied pressure, solubilization increased with extending time of pressurization. In case of 0.1 M NaCl and pH 6, solubility of myofibril pressurized at 200 MPa gradually increased with time, while those of 300 to 500 MPa reached at maximal values at 2.5 minutes and they remained at a constant level thereafter. The solubility at pH 6.0 was slightly higher than that at pH 7.0. The maximal protein concentration was about 0.8 mg/ml in pH 6 and 0.6 mg/ml in pH 7, indicating that 6–8% of myofibrillar protein was solubilized by pressure treatment in 0.1 M NaCl. Solubility change in 0.2 M NaCl at pH 6 was comparable to that at 0.1 M NaCl except 200 MPa, in which case the solubility was similar to those above 300 MPa. The maximal protein concentration was slightly higher than that at 0.1 M NaCl. There was a notable solubility change in 200MPa at pH 7. The solubility of myofibril treated at 200 MPa markedly increased with extending time of pressure application. The protein concentration reached at 3 mg/ml after 30 minutes of pressure application, which indicated approximately 30% of myofibrillar proteins were solubilized by pressure application of 200 MPa. The protein concentrations in 300–500 MPa at 0.2 M NaCl were comparable to those at pH 6.

We performed SDS-PAGE to clarify what kinds of myofibrillar proteins were solubilized by pressure application. Fig. 2a shows SDS-PAGE pattern of solubilized fraction at 0.1 M NaCl. Actin, tropomyosin, and troponin were solubilized by pressure treatment. The densities of these protein bands seemed almost the same from 2.5 to 30 minute of pressurization at 300 and 400 MPa. On the other hand, those in 200 MPa were less compared to 300–400 MPa, although the densities of the bands of thin filament components increased with extending time of pressure treatment. Solubilization of thin filament components at 100 MPa was a little. Myosin heavy chain was observed in the supernatant pressurized at 300 MPa for 2.5 to 5 minutes at pH 7, but the band was not observed in the samples pressurized for 10 to 30 minutes. Fig. 2b shows SDS-PAGE pattern of solubilized fraction at 0.2 M NaCl. Solubilization of thin filament components occurred as well as the case of 0.1 M NaCl. The bands of these proteins at 200 MPa were denser than those in 0.1 M NaCl regardless of pH, and they were comparable to those in 300–400 MPa. Solubilization of myosin heavy chain was observed in pH 6 at 200 MPa from 2.5 minutes to 10 minutes, while there were no myosin heavy chain bands in 100, 300, and 400 MPa. As shown in solubility change (Fig. 1), solubility in 0.2 M NaCl notably increased at 200 MPa. There was marked increase of myosin heavy chain band with extending time of pressure application at 200 MPa and pH 7. In case of 300 MPa, the maximal solubilization of myosin heavy chain was observed at 2.5 minutes, and the density of the band decreased with extending time, and the band was not detectable in the solubilized fraction treated for 15–30 minutes. This suggests that solubilized myosin becomes insoluble; in other words, myosin forms aggregates with extending duration of pressure application at 300 MPa. Myosin heavy chain was not observed in 400 MPa.

When myofibril suspension was pressurized, it formed a gel except 100 MPa in 0.1 M NaCl at pHs 6 and 7. Five minutes of pressure application was enough to form a gel, and there was no substantial difference in gel strength between 5 and 15 min of pressurization. The strength of the gel formed in 0.1 M NaCl almost lineally increased with applied pressure, whereas the gels formed in 0.2 M NaCl had almost the same gel strengths regardless of applied pressure except 200 MPa, in which case the gel strength was rather low than the others. Pressure-induced gels formed at pH 6 were firmer than those at pH 7, and such tendency was similar to that observed in myosin gel. The gel strengths of pressure-induced gels were comparable to that of the heat-induced gel formed in the same solvent condition. Those of thermal gel formed in 0.1–0.2 M NaCl at 60 °C were 8 to 10 gf at pH 6 and about 6 gf at pH 7.

Microstructure of pressure-induced myofibrillar gel was observed with scanning electron microscopy (Fig. 4). Pressure- and also heat-induced myofibrillar gels were composed with a network of myofibrils. The structure of myofibril was retained in 0.1 M NaCl, while disruption of myofibril was observed in 0.2 M NaCl at pH 7 and pH 6 as well (not shown). The disruption of myofibrils corresponds to solubilization of myofibrillar proteins. The surface of myofibrils in heat-induced gel in 0.1 M NaCl seemed to be smooth, while that in pressure-induced gel was spiny. Spiny structure was few in 200 MPa; however, it was obvious in the gels formed at higher pressure such as 400 and 500 MPa. It is possible that solubilized myofibrillar proteins form these spines, and they play a role in the network formation of myofibrils.

Pressure treatment of meat patty induced gelation; however, the induced gel was not enough firm. Heating of pressurized meat patty made it stiff. Breaking strength of pressure-heat-treated meat patty was much higher than that of heat-treated one, and the former was elastic compare to the latter.

Conclusion

It is concluded that high hydrostatic pressure induces solubilization of myofibrillar proteins and also induces gelation of myofibrils at high protein concentration. Thin filament components were easily solubilized with pressure application; however, the solubilization of myosin depended on the magnitude and duration of pressure application, salt concentration and pH. Pressure-heat-treatment improved rheological properties of meat patty.

Literature

1. R.R. Swezey and G.N. Somero, Biochemistry, 24, 852 (1985).
2. S.J. Tumminia, J.F. Koretz and J.V. Landau, Biochim. Biophys. Acta, 1040, 373 (1990).
3. K. Yamamoto, T. Miura and T. Yasui, Food Structure, 9, 269 (1990).
4. K. Yamamoto, S. Hayashi and T. Yasui, Biosci. Biotech. Biochem., 57, 383 (1993).
5. A. Suzuki, M. Watanabe, K. Iwamura, Y. Ikeuchi and M. Saito, Agric. Biol. Chem., 54, 3085 (1991).
6. A. Suzuki, N. Suzuki, Y. Ikeuchi and M. Saito, Agric. Biol. Chem., 55, 2467 (1991).

Figures

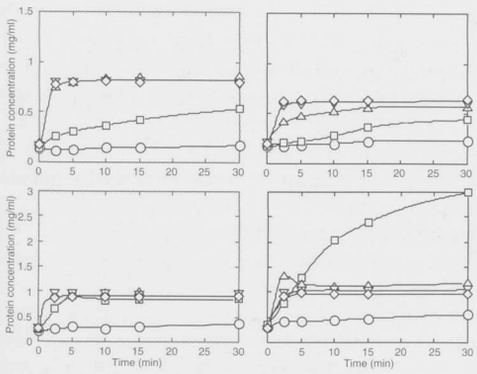

Fig. 1. Pressure-induced changes in solubility of myofibrils in 0.1 M (upper) and 0.2 M NaCl (lower) and at pH 6 (left) and pH 7(right). Circle; 100 MPa, square; 200 MPa, triangle; 300 MPa, reversed triangle; 400 MPa, and diamond; 500 MPa.

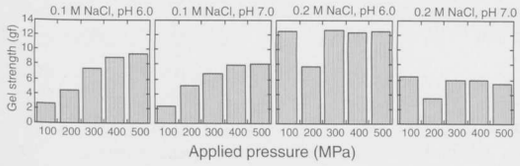

Fig. 3. Gel strength of pressure-induced myofibrillar gel.

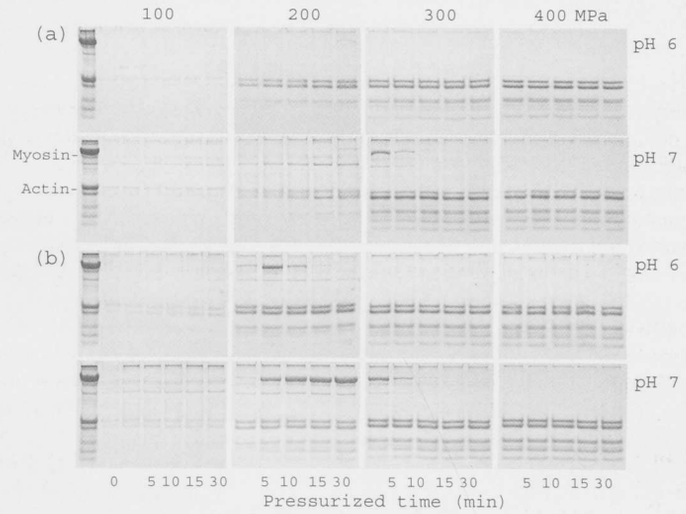

Fig. 2. SDS-PAGE profiles of pressure-induced solubilized fraction of myofibril in 0.1 M (a) and 0.2 M (b) NaCl. The left end lanes in 100 MPa represent myofibrils.

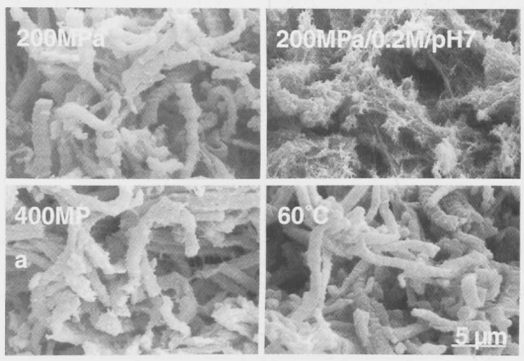

Fig. 4. Scanning electron micrographs of pressure- and heat-induced myofibrillar gel. Pressure-induced gels were formed from myofibrils suspended in 0.1 M NaCl at pH 6 with applied pressure of 200 MPa and 400 MPa (left). The upper right is a pressure-induced gel formed in 0.2 M NaCl at pH 7 and 200 MPa. The lower right is a thermal gel heated in 0.1 M NaCl at pH 6.