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LOW TEMPERATURE THAWING BY USING HIGH-PRESSURE

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RÉSUMÉ / *SUMMARY:*

The melting point of ice becoms lower in high pressure than 0 °C. This physical principle was applied to thaw the frozen fish-blocks and surimi-blocks . Fish or Surimi-blocks were thawed at -5 °C ~ -15 °C under about 196 MPa. However, the texture of fish meat became harder by denaturation of protein in high pressure. The thawing time by this method became short and depended on the temperature of the working fluid.

MOTS-CLÉS / *KEYWORDS:*

Thawing, High pressure,Fish meat,Melting point, Ice

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1. INTRODUCTION

The frozen food quality after thawing depends on the temperature of thawing as well as on the quality of materials before freezing and storage temperature.

In this study, we intended to thaw the frozen food,in particular frozen tuna fish meat and "surimi" blocks which are the row material of "kamaboko", at lower temperature than the freezing point.

It is clear that the temperature of the substance have to be risen up to the intrinsic freezing points of the substance in order to thaw the frozen fish meat or surimi blocks. Freezing points of theses foods are lower than the pure water freezing point. In general, the degree of these depressions for food materials are from 1 to 5°C . The dependence of the melting point of the pure water ice on pressure can be described with the following equation

$$\frac{dT}{dp} = -0.074\ ^{\circ}C/MPa,$$

this equation was derived from the Clapeyron-Clausius equation/1/. The phase diagram of water in high pressure regime is shown in Fig.1, which was measured by Bridgman/2/ and other researchers. The boundary curve line between the liquid phase and the solid one, especially from 0 to 200 MPa, was focused on this study.

According to this diagram, the melting point of pure water ice decreases with pressure increasing to 200 MPa. Using this physical principle of the melting point depression by pressure, we intended to thaw frozen foods at low temperature under high pressure.

2. MATERIALS AND METHODS

Sample specimen

Pure water ice blocks, frozen tuna meat blocks and surimi blocks were subjected to this studies. A copper-constantan thermocouple was inserted every sample at the center of it. Theses samples were stored for more than one week at -30 C in a chest type freezer.

Ice blocks were 50mmϕ x 60mm length respectively. Tuna fish meat blocks were almost 26 x 24 x 70mm and weighed 30 40g. Frozen surimi blocks were almost 54 x 42 x 27 mm and weighed about 60 g respectively.

Apparatus

The schematic diagram of apparatus is shown in Fig.2-1 and it consists of three parts. One is a high pressure endurable vessel, the other one is a manual operating booster pump and they are connected together with stainless steel tube , and the last one is a temperature recorder which doesn't appear in this figure. The pressure in the vessel is measured by a Bourdon-tube pressure gauge being measurable to 245MPa.

The pressure endurable vessel(made by Hikari Koatsu Co.Ltd.), which is fully shown in Fig.2-2, is cylindrical vessel and is about 350 ml of the test chamber. The free piston which is set in the test chamber separates the working fluid of the test section from the manual booster pump's. This vessel has two sapphire glass observing windows and they are opposite to each other. Thermocouple wires are lead into the test chamber through pin holes in the plug of the pressure vessel. High pressure in the vessel is sealed by insulate tapered junctions of thermo-couple lead wires.

High pressure treatment

A specimen which has been stored in the freezer was taken out and suspended by the lead wires in the test chamber. Just before the sample being set to the test section, the temperature of the working fluid in the test chamber was controlled through the temperature of the jacket being regulated. Starting the temperature recorder , the manual pressure booster pump was operated to maintain the pressure to the fixed value. The pump was sometimes pressed in order to keep the pressure in the vessel at the constant value while the sample being thawed. If the temperature of the specimen would begin to increase without the pressure decreasing , the thawing of sample was determined to reach the final stage. Then, the pressure valve was released for pressure purging.

3. Results and discussion

Temperature history in thawing process

Typical temperature histories in thawing processes which were operated on surimi blocks are shown in Fig.3-1 and 3-2.

In figure 3-1, the initial temperature of the sample was -13°C and the pressure was 98 MPa. The temperature suddenly rose up by 2°C just after the pressure rising, and then it fell down to -17°C by compressing to 98 MPa. It was necessary to add the pressure to keep the fixed value in the test chamber, because the pressure in the vessel gradually decreased with the volume of sample becoming smaller by thawing. After few minutes, the sample temperature began to rise without pressure decreasing. We decided that this time was the final point of the thawing, since a variation of sample volume arising from the thawing didn't appear in the vessel. When the pressure in the vessel was relieved , the temperature of the sample jumped up over 0°C and the temperature of working fluid fell down to the sample's one. This phenomenon is brought from the adiabatic expansion of the fluid and the thermal volume expansion coefficients of water and oil being opposite to each other near 0°C.

In figure 3-2, the profile of the temperature is similar to the previous one, except the initial temperature of the sample was higher than the Fig.3-1. This caused the sample temperature not to rise up just after the pressure loading. Increasing the pressure in the vessel ,the temperature of the sample fell down to the equilibrium temperature which was determined to 196 MPa in the vessel. The working fluid temperature rose up at first and then fell down gradually to the initial temperature . In this case, the final point of the thawing stage was decided by the same manner.

Phase diagram of food materials

Applying the above method, the melting points(thawing temperature) of pure water ice ,tuna fish meat and surimi were measured in high pressures. Figure 4 shows the phase diagram of pure water ice and other materials. Open circles and solid line was derived by Bridgman's/2/ data for pure water ice and lower part solid circles were measured in this work for the pure water. The results from this works were little bit lower than the Bridgman's ones. However, they were consistent with each other within the experimental accuracy. Solid circles and half solid circles of right part show the melting points of the surimi blocks and tuna fish meats being determined in this work, respectively. These experimental data are represented by broken line.

On this phase diagram, if a frozen fish meat block would be pressed at -7 °C ,its melting point moved down along the broken line in Fig.4. This broken line is almost parallel to the pure water phase boundary line.

Requiring time for thawing

Figure 5 shows the thawing curve of surimi blocks in various pressure conditions for thawing. The solid line which has not circles shows the thawing curve in the atmospheric pressure at 25°C. The temperature rose up steeply at the first stage and then it rose up slowly between -5 and 0 °C. This region is the so-called 'maximum crystal growth zone'. The requiring time for thawing in high pressure was shorter than the time in the atmospheric pressure at room temperature. Addition to the requiring time cut down, the temperature of the samples were maintained at lower temperature than 5 °C while they were thawing.

By using the high pressure for thawing , the temperature of materials could be held at lower and the process of thawing could be completed within shorter time than under the atmosphere pressure. However, the high pressure led to the denaturation of protein of the specimens , and so the color of the fish meat changed from the natural bright red to grayish brown. Texture of the fish meat and surimi blocks became harder than the row material's texture ,that has been studied in detail by Taguchi et al,/4/.

4 Concluding remarks

The application of high pressure for thawing to the frozen food could keep the temperature of the food lower than the maximum crystal growth temperature and can reduce the time for thawing, but the denaturation occurred in the test samples. It may be concluded that in applying the high pressure for thawing ,it is necessary that the pressure treatment will be completed as soon as possible ,and if there would be any sensible materials for pressure ,it was necessary to keep the pressure low in the vessel. In conclusion,this treatment may be useful to apply not for thawing the frozen food ,but for processing the food materials under the freezing temperature of the food stuff, let's say the seasoning of frozen food in freezing condition.

The authors are grateful to Mr. Y.Shimabe and Ms.M.Mitsui for their energetic experimental works.

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Le dégèlement à température basse sous haute pression

RÉSUMÉ: Nous avons dégelé de la glace et de la chair de poisson congelée stockée à -10°C. Les échantillons ont été mis dans un petit contenant à pression et dégelés dans la huile, en état statique et à pression de 196MPa. Le contenant utilisé a une fenêtre et un thermocouple pour mesurer la température des échantillons.

A mesure que la pression augmente, la température de la glace baisse; avec la pression de 196MPa, elle baisse jusqu'à -20°C.

Pour tenir à 196 MPa la pression à l'intérieur du contenant, on doit de temps en temps y donner pression. Cette decompression resulute de la fonte de la glace qui provoque le changement de la densité intérieure. La fin du dégèlement s'annonce avec l'arrêt de la décompression et la la lente montée de la température à l'intérieur.

Le temps du dégèlement dépend de la grandeur des échantillons et de l'écart entre la température de début des échantillons et celle de l'huile dans le contenant.

La chair de poisson, après le dégèlement, perd sa teinte originale. C'est que la haute pression a dénaturé la protéine qui y est contenue.

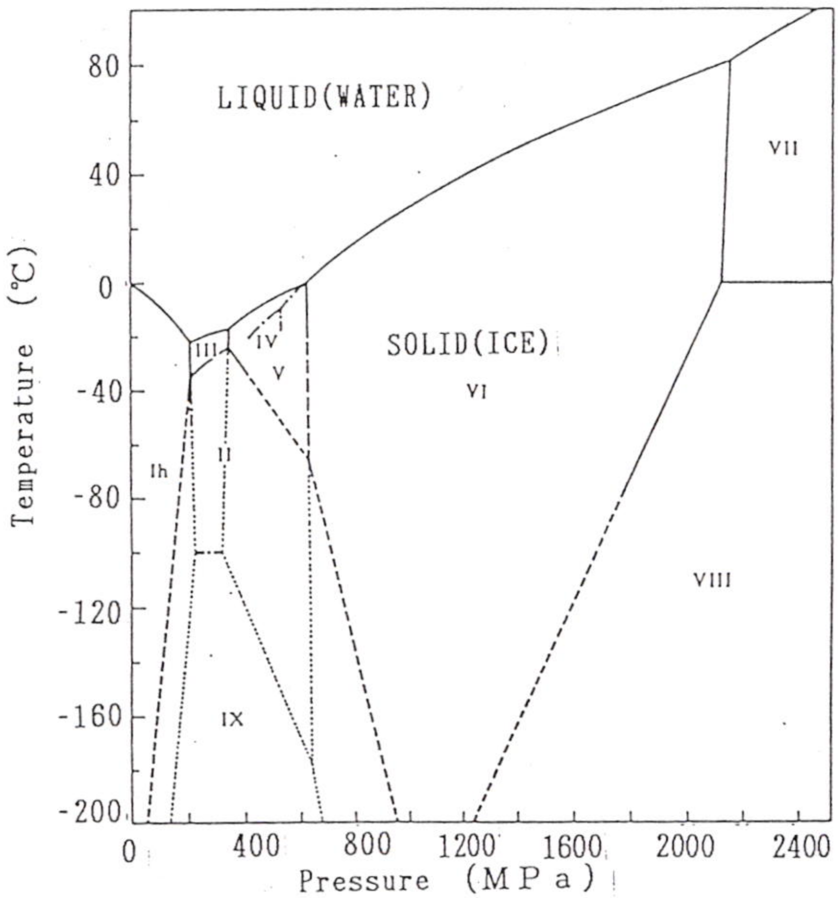

Figure 1 The phase diagram of ice /3/.

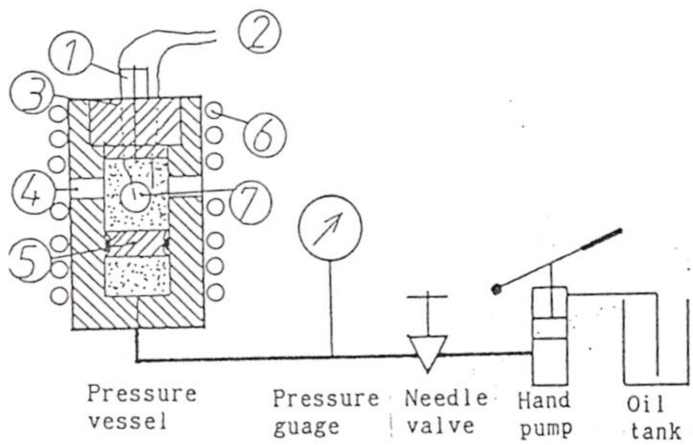

Figure 2-1 Schematic diagram of apparatus

1. Air purge valve
2. Thermocouples
3. Pressure tight plug
4. Window
5. Free piston
6. Pipes for cooling
7. Sample

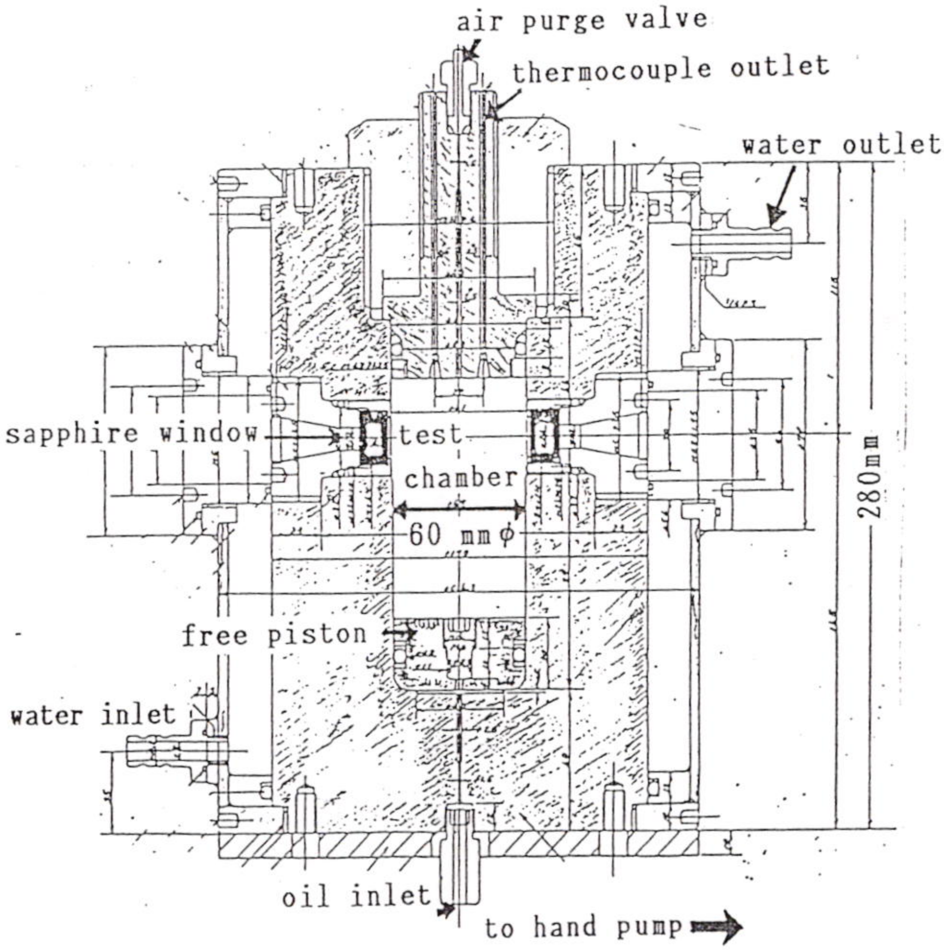

Figure 2-2 Detail of pressure vessel

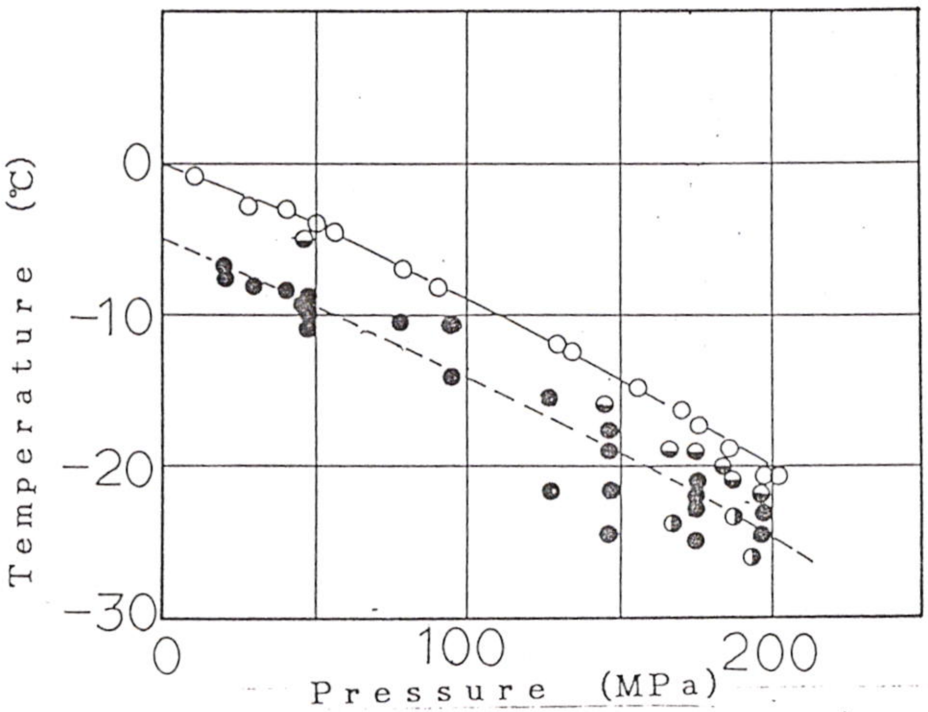

Figure 4- Phase diagram of pure water and other ones in complex materials at high pressure .

○;Bridgman's data for water,

⊖;this works for water,

◑;"tuna fish" meat,

●;"surimi" minced fish meat block

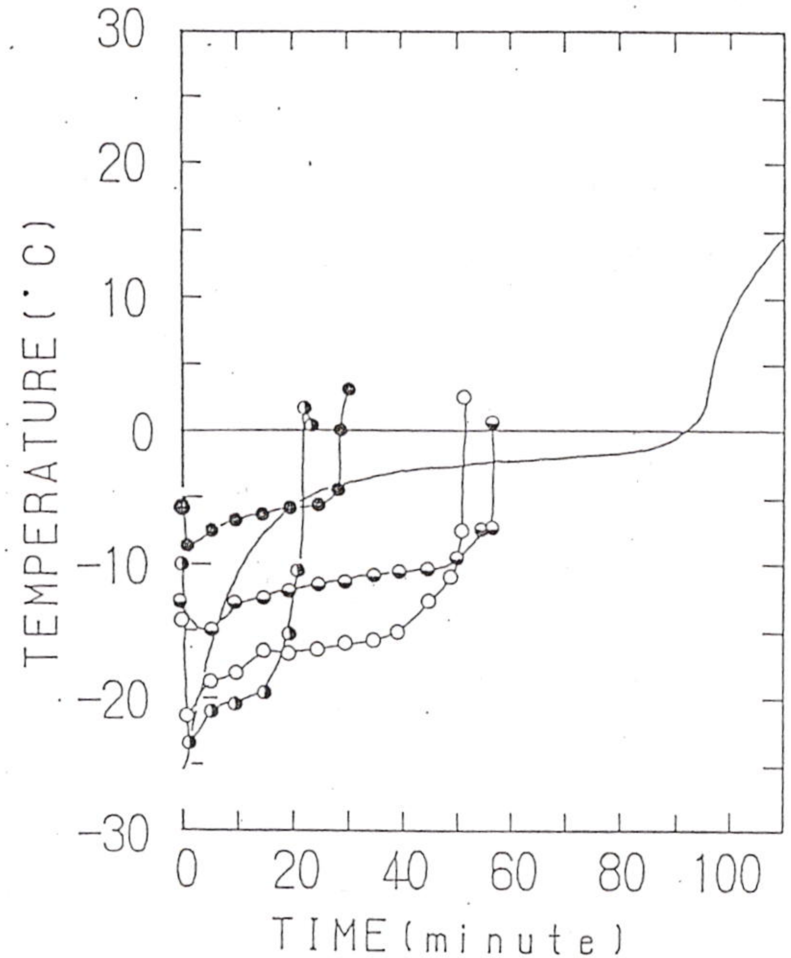

Figure 5 Comparison of thawing time for surimi at various pressures

solid line; at natural atomospher

●; at 49 MPa, ○; at 147 MPa,

⊖; at 98 MPa, ◑; at 196 MPa,

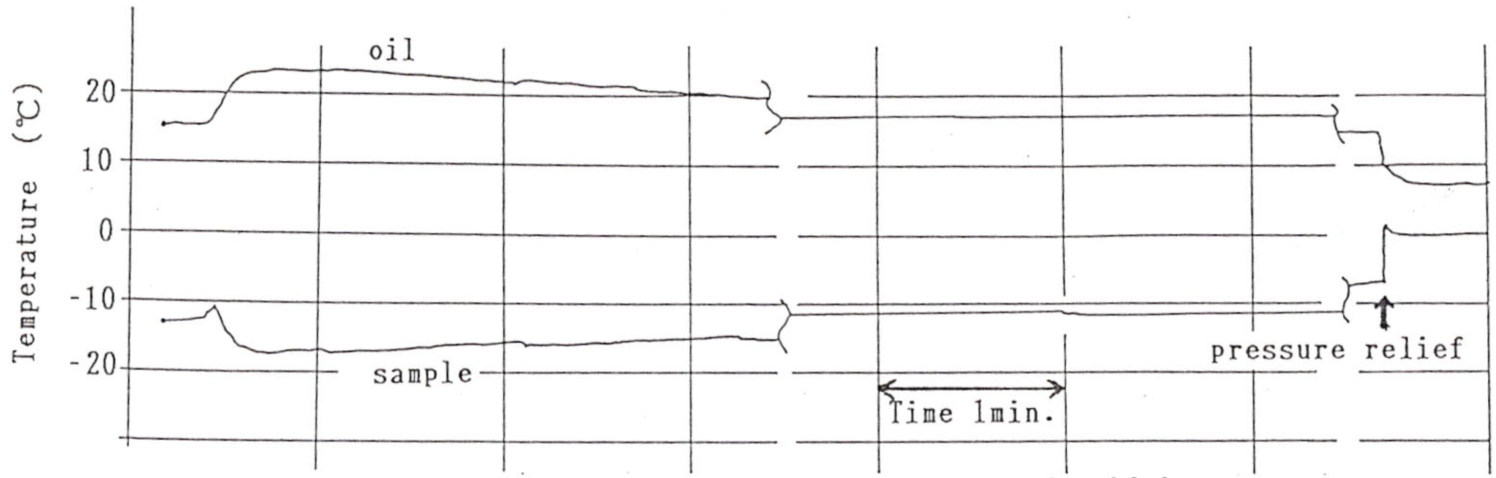

Figure 3-1 Temperature history in thawing process under high pressure at 98 MPa. Sample weight:57.65g

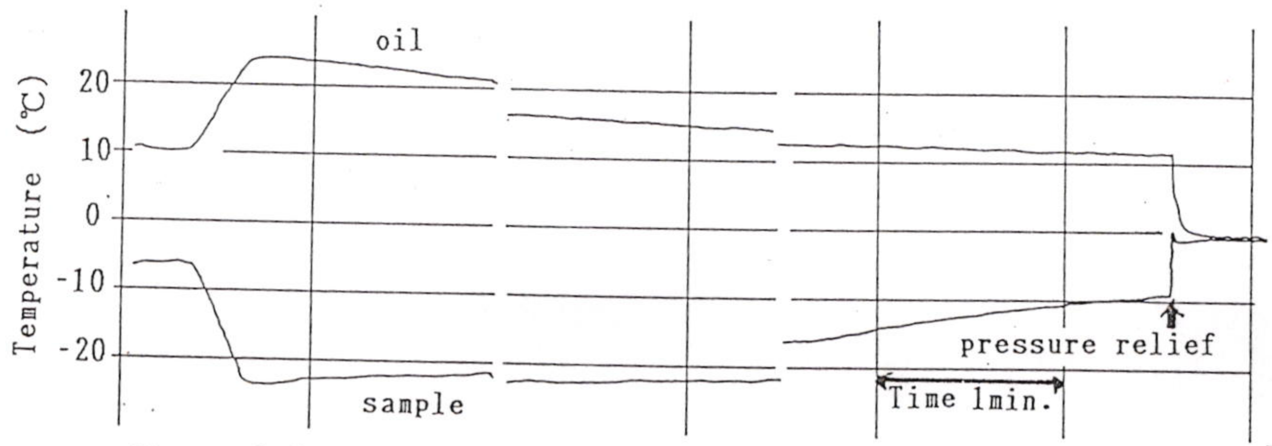

Figure 3-2 Temperature history in thawing process under high pressure at 196 MPa. Sample weight:36.28g