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Textural Properties of Pressure-Induced Gels of Food Proteins Obtained under Different Temperatures

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Gelation process of ovalbumin, egg yolk and soy protein was carried out by pressurization from 0.1 to 500 MPa under a temperature range from -20 to 100 °C, and hardness, cohesiveness and gumminess of gels formed were determined. Pressure-temperature dependency of protein gelation strongly depends on the protein. Ovalbumin and soy protein gelation can be achieved under subzero temperatures. Ovalbumin gelation shows a minimun at 25 °C, however, gelation of soy protein does not show a such minimum. In case of egg yolk, gelation can not be achieved at temperatures below 10 °C.

1. INTRODUCTION

The pressure-temperature diagram for the inhibition of microbial vegetative cells or that for protein denaturation has an elliptical shape [1,2,3]. A such shape indicates that heat can suppress pressure effects or pressure can suppress temperature effects. In case of egg white, it was also found that a pressure up to 180 MPa can suppress heat-induced gelation [4]. Nevertheless, little is known about the pressure-temperature phase diagram of protein gelation in a wide range of temperatures and especially at subzero temperatures. Therefore, we carried out the pressure gelation process under a range of temperatures from -20 to 100 °C and a pressure range from 0.1 to 500 MPa for three typical food proteins, ovalbumin, egg yolk and soy protein, and we measured three basic textural properties, hardness, cohesiveness and gumminess.

2. MATERIAL AND METHODS

Crude ovalbumin was further purified by the procedure of Kekwick and Cannan [5] with modifications. The final purity was 93.5 %. Acid-precipitated soy protein was prepared by the procedure of Bau *et al* [6]. Fresh eggs were obtained from a poultry.

Ovalbumin and soy protein were dissolved in distilled water by gentle mixing. The resultant solutions were introduced in polyethylene bottles. Since gels of soy protein were particulary sticky and difficult to remove, bottles were coated with liquid parafin before being filled with the protein solution. After being separated from the egg white, egg yolk was gently mixed and introduced in a polyethylene bottle.

Pressure-induced gelation was carried out in a pressure bomb (inside size : 2.5 cm in diameter and 7.5 cm in height) equipped with a hand-type oil pressure generator (type KP5B, Hikari Koatsu Co., Hiroshima). Kerosene was used as the pressure medium. The bomb was maintained at the desired temperature by immersing it in a water-ethanol bath. Before pressurization, the polyethylene bottles were incubated 15 minutes at the given temperatures.

Heat-induced gels were obtained by heating bottles for 10 minutes in a boiling water bath.

After the pressure or heat treatment, gels were kept for 30 minutes at room temperature and then carefully taken out of the bottle and cut in a disc of desired height. Hardness, cohesiveness and gumminess were measured using a rheometer (RE 3305, Yamaden Co., Japan).

3. RESULTS

Ovalbumin

A 15 % (w/w) solution of ovalbumin was submitted for 30 minutes to a pressure of 0.1, 100, 210, 300, 400 and 500 MPa under the following temperatures : -20, -5, 10, 25 and 50 °C. Gels formed under the following conditions exhibited enough firmness for the texture measurements : 210 MPa at -20 °C, 300 MPa at -5, 10 and 50 °C and 400 MPa at 25 °C. Table 1 sumarizes the textural properties of gels formed under 500, 400 and 210 MPa. For temperatures ranging from -5 to 50 °C, hardness shows a minimum at 25 ° C. At - 5 °C, gels with the same high hardness were formed independantly of the pressure applied, even under 300 MPa . On the contrary, at the other temperatures, hardness of gels increased with increasing pressure. Pressure-induced gels, except those obtained under 300 MPa at 10 and 50 °C (data not shown), were more elastic and more difficult to breake than heat-induced gels even if some of them were as hard as heat-induced gels.

At -20 °C, hard gels were obtained at 210 MPa. They were less white and less homogenous than those obtained at the other temperatures. Their structure was slightly porous with a slight syneresis. At 300, 400 and 500 MPa , beige and sponge-like soft gels were obtained. Differences in gels texture observed for -20 °C were probably due to the water state since water is frozen under 300 MPa (type III ice) or 400 and 500 MPa (type V ice), whereas it is still liquid under 210 MPa [7].

In general, we found that both pressure and temperature only slightly affect the cohesiveness (table 1). Nevertheless, all pressure-induced gels were slightly less cohesive than heat-induced gel. It is of our interest to note that gels formed at -20 °C under 300, 400 and 500 MPa exhibit a cohesiveness similar to others gels despite of the syneresis. This may be explained by the water re-entry into the gel after the first compression-decompression cycle.

Gumminess followed the same tendency as hardness.

Egg yolk

Egg yolk was pressurized for 30 minutes at 0.1, 100, 210, 300, 400 and 500 MPa at -20, -5, 3, 10, 25, and 50 °C. At 10, 25 and 50 °C, gels being enough firm for texture measurements were formed respectively at 500, 400 and 300 MPa. The hardness of gels increased as the pressure increased at a given temperature. Similarly, at a given pressure, hardness increased with increasing the temperature. All pressure-induced gels of egg yolk were considerably softer than heat-induced gels. They were more yellow and unbreakable by compressing with fingers. Concerning the cohesiveness, no special differences were noted among all the gels formed including heat-induced gels.

No gel were formed at temperatures below 10 °C even when egg yolk was pressurized at 500 MPa. Under these conditions it only formed highly viscous solutions. Since the composition of egg yolk is complex, some proteins or other egg yolk constituents can have a negative effect on the gelation at low temperatures including subzero temperatures.

Table 1
Textural properties of heat and pressure-induced gels of ovalbumin and soy protein.
Disc size for texture measurement was 0.9 cm in diameter and 0.7 cm in height for ovalbumin gels and 1 cm in diameter and 0.8 cm in height for soy protein gels. Clearance was respectively adujsted to 0.35 and 0.4 cm

Conditions for gel formation		Gels of ovalbumin (15% w/w)			Gels of soy protein (17% w/w)		
Temperature °C	Pressure MPa	Hardness g/cm^2	Cohesiveness T.U.[b]	Gumminess T.U.[b]	Hardness g/cm^2	Cohesiveness T.U.[b]	Gumminess T.U.[b]
100[a]	0.1	580.3	0.800	464.30	317.2	0.912	289.26
50	500[c]	647.5	0.804	520.77	156.9	0.820	139.98
50	400[c]	275.2	0.745	204.93	136.7	0.896	122.07
25	500[c]	290.2	0.771	222.36	113.4	0.950	107.77
25	400[c]	158.1	0.746	117.85	108.1	0.942	102.09
10	500[c]	379.1	0.746	282.42	84.0	0.930	78.27
10	400[c]	412.9	0.753	321.83	70.4	0.870	61.26
-5	500[c]	485.6	0.694	336.99	78.5	0.887	69.58
-5	400[c]	476.2	0.738	367.18	59.7	0.829	49.37
-20	500[c]	67.6	0.727	49.23	0	0	0
-20	400[c]	102.2	0.752	76.76	0	0	0
-20	210[c]	366.5	0.695	254.11	13.58	0.802	10.95

[a] Heated for 10 minutes in a boiling water bath. [b] Texture Unit. [c] Pressurized for 30 minutes.

Soy protein

A 17 % (w/w) soy protein solution was pressurized under 0.1, 100, 210, 300, 400 and 500 MPa at -20, -5, 10, 25 and 50 °C for 30 minutes. Gels having enough firmness for texture measurements were formed under 210 MPa at -20 °C and under 300 MPa at -5, 10, 25 and 50 °C. Table 1 shows the textural properties of gels obtained under 210, 400 and 500 MPa. Except for gels obtained at -20 °C, the gel hardness continuously increased as the pressure increased at given temperatures. Similarly, except at 210 MPa, the hardness continuously increased with the temperature, at given pressures. The pressure-induced gels were softer and more deformable without breaking and less white than heat-induced gels.

At -20 °C, a soft gel was formed at 210 MPa. It was smoother than gels obtained at other temperatures. At higher pressures under - 20 °C, where water is under ice state, no gels were formed.

4. CONCLUSION

Pressure-temperature dependency of protein gelation strongly depends on the protein. Ovalbumin gelation shows a minimum at 25 °C indicating that in lower or higher temperatures, gelation can be achieved at lower pressures. However, egg yolk and soy protein do not show a minimum : gelation effectiveness continuously changes with the temperature. That is, soy protein gelation progressively decreases with lowering the temperature and egg yolk gelation shows even more drastic decrease. Moreover, at subzero temperatures, the state of water seems to affect the formation and the structure of gels.

From a practical point of view gelation under low temperatures and especially under subzero temperatures may be of interest in food industries since depending on the protein :

- gels with new textures can be obtained when gelation is carried out under conditions when water is in ice state;
- gels can be conveniently formed at low pressure and low temperature;
- moderate pressures and low temperatures could be used to sterilize protein solutions without strongly modifing their texture.

Nevertheless, further experiments are needed to better understanding the gelation process and reasons of the different pressure-temperature dependency observed among proteins.

5. REFERENCES

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