加熱および水漬中の塩蔵クラゲのレオロジー的性質

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The Rheological Properties of Salted Jellyfish during Cooking and Dipping in Water

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The rheological properties of salted jellyfish were examined by stress-relaxation measurement and rupture strength measurement. The samples used in this work were 6 kinds of salted jellyfish imported from southeast Asia. Differences between the rheological properties was not recognized between these samples. The texture of the samples depended on the heating temperature and the standing time in water. Namely, the elastic modulus of the sample standing in water increased in the first 2 days, and then decreased. Both values of elastic modulus and viscosity rose steeply at 50°C or 60°C. On the contrary the rupture strength increased with heating temperature from 30°C to 50°C, and then fell at 60°C. The results mainly come from the shrinkage of collagen in jellyfish and the destruction of tissue with peeling of the layer structure.

Jellyfish belongs to the class *Scyphozoa* in the *Coelenterata*.[1] Some large jellyfish of the order *Rhizostomeae* are important in Chinese food owing to their textures. The jullyfish are fixed and preserved with a mixture of salt and alum, and semi-dried materials are marketed. Recently, cooked jellyfish which have been desalted in water, then boiled, and finally dipped in water, have appeared on the market.

The texture characteristics of cooked jellyfish depend on the heating temperature and the standing time in water. We are interested how the unique texture of jellyfish occurs in the processing.

In this work, the texture change of jellyfish in processing have been examined by stress-relaxation experiment and rupture strength measurement.

Materials and Methods

Materials

The salted jellyfish was processed in southeneast Asia. Six kinds of salted jellyfish were imported from southeast Asia: Malaysia (Malacca), Indonesia (Kota Bharu), Indonesia (Medan), Myanmar, Thailand (Ranong), and Philippines. They are the main countries exporting salted jellyfish. The species of jellyfish and the manufacturing process are considered to be not different each other.

The salted jellyfish were washed with water, and then they were dipped in water to desalt.

A desalted jellyfish was equally cut to yield at least 16 strips 3 cm × 6 cm. The heating procedure was described as follows; each piece was boiled at the designated temperature, *i.e.* 30°C, 40°C, 50°C, 60°C, and 80°C for 30 min, respectively. Both the heated sample and the unheated sample were dipped in water at 5°C for 9 days. Each sample was examined for each day of the nine days.

Stress-relaxation Measurement

The stress-relaxation experiments were carried out by using a TENSIPRESSOR Model TTP-50BX (Taketomo Denki) at room temperature. Two types of cyrindrical plungers were used, and their size were 1.8 cm and 0.6 cm in diameter. The constant strain was 0.5 as a result of press.

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Table 1. The rheological parameters of the samples after heating at 60°C

Exporting country	E_0	E_1	E_2	η_1	η_2	τ_1	τ_2
Malaysia (Malacca)	3.75±0.66	2.59±0.35	1.07±0.23	8.21±0.74	1.23±0.24	32.5±2.0	1.16±0.03
Myanmar	2.38±0.41	1.73±0.31	0.64±0.11	5.79±1.15	0.74±0.12	32.8±1.6	1.16±0.04
Indonesia (Kota Bharu)	3.58±0.67	2.45±0.44	0.96±0.23	7.83±1.20	1.09±0.25	32.5±2.2	1.15±0.03
Indonesia (Medan)	2.97±0.52	2.00±0.36	0.79±0.19	7.26±0.84	0.89±0.19	38.3±3.2	1.17±0.05
Philippines	5.15±0.35	3.30±0.28	1.55±0.34	8.57±1.10	2.00±0.17	25.7±1.7	1.10±0.54
Thailand (Ranong)	4.91±0.46	3.29±0.31	1.45±0.19	9.11±0.65	1.62±0.24	28.3±2.6	1.10±0.05

* $E_0, E_1, E_2 \times 10^{-2}$ (N/m²); $\eta_1, \eta_2 \times 10^{-3}$ (Pa·s) τ_1 τ_2 (s)

All measurements were repeated 8 times for each strip of jellyfish.

The stress-relaxation curves were analyzed by using the progressive approximate method.[3,4) The instantaneous (compression elastic) modulus (E_0) was calcultated from the load when the compression reached maximum. The approximate equation of the stress-relaxation can be expressed as follows:

$$p(t)=e_0 \sum_{i=1}^{n} E_i \exp(-t/\tau_i) \qquad (1)$$

where $p(t)$ is stress, e_0 the constant strain, t the time, E_i the elastic modulus of the i-th element, and τ_i the stress-relaxation time of the i-th element. The stress-relaxation time of the i-th element (τ_i) is related to the viscosity (η_i) and elastic modulus (E_i) of the i-th element as eq. (2).

$$\tau_i=\eta_i/E_i \qquad (2)$$

The instantaneous modulus (E_0) is defined as follows:

$$E_0=E_1+E_2+\cdots+E_n \qquad (3)$$

Rupture Strength Measurement

The rupture strength was measured with the same apparatus as used in the stress-relaxation experiment at room temperature. The conical plunger (cone-angle 50°) pushed the samples at the rate of 120 mm/min. The experimental results shown in this paper are the average of 10 experimental values for one sample.

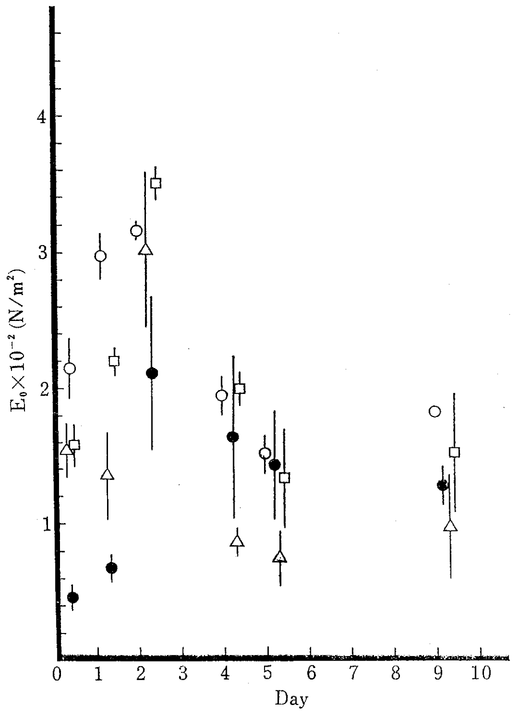

Fig. 1. The relationships between the instantaneous elastic modulus (E_0) and the standing time in water.
●; the value for sample heated at 50°C.
□; the value for sample heated at 60°C.
○; the value for sample heated at 80°C.
△; the value for unheated sample.

Results and Discussion

In this work, all stress-relaxation curves could be analyzed by twice procedures of the progressive approximate method, *i.e.* n=2 in eq (1).

The rheological parameters of the 6 samples after the heating at 60°C are sammarized in Table 1. These rheological parameters did not depend on the samples which were imported from different countries.

Figure 1 shows the dependence of the instantaneous modulus (E_0) on the standing time in water. The E_0 values for the samples after heating at 50°C, 60°C, and 80°C and also for the unheated

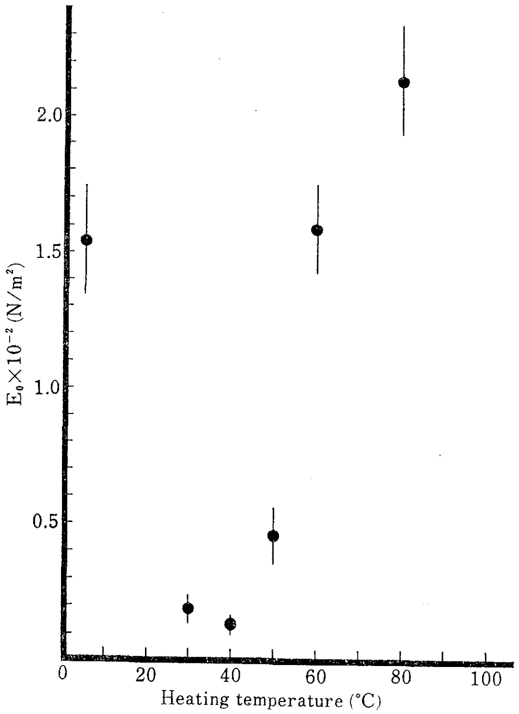

Fig. 2. The relationships between instantaneous elastic modulus (E_0) and the heating temperature. The heating was done for 30 min at each temperature.

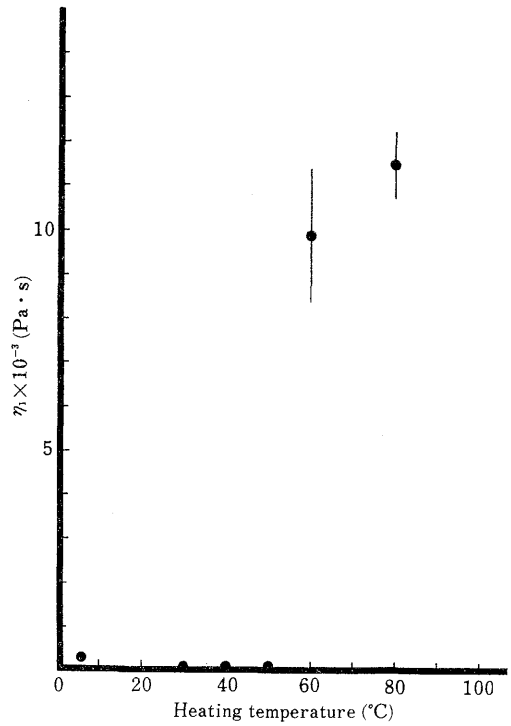

Fig. 3. The relationships between the viscosity of the 1st element (η_1) and the heating temperature. The heating was done for 30 min.

sample increased in the first 2 days, and steeply decreased at the fifth day. After the fifth day, they were almost constant (at least for 4 days).

The first increase of the elastic modulus comes from swelling of the sample by dipping in water, and following deceases come from the softening or fragility of the samples by the destruction of tissue with peeling the layer structure.

Figures. 2 and 3 show the dependence of E_0 and η_1, on the heating temperature, respectively. The other elastic moduli (E_1 and E_2) and another viscosity (η_2) exhibited a similar tendency as shown in Figs. 1 and 2, respectively.

As shown in Fig. 2, the E_0-value steeply falled from *ca.* 1.5×10^2 (N/m^2) for the unheated sample to *ca.* 0.15×10^2 (N/m^2) for the sample heated at 40°C and then steeply increased to *ca.* 2.1×10^2 (N/m^2).

As shown in Fig. 3, the viscosity of the 1st element (η_1) slightly decreased from *ca.* 0.6×10^3 (Pa・s) for the unheated sample to *ca.* 0.05×10^3 (Pa・s) for the sample heated at 40°C and then steeply increased to *ca.* 12×10^3 (Pa・s) with an increase the heating temperature.

The dependence of the rupture strength on the heating temperature is hsown in Fig. 4. The rupture strength of unheated sample indicated the highest value (4.4×10^4 N/m). When the sample was boiled at 30°C, the rupture strength of the sample decreased to 3.4×10^4 (N/m). Then the rupture strength linearly increased to 4.2×10^4 (N/m), as the heating temperature increased up to 50°C. However, the value of rupture strength steeply decreased to 1.2×10^4 (N/m) on the 60°C heated sample and to 0.8×10^4 (N/m) on the 80°C heated sample. The tendency of the rupture strength were significantly different from other rheological parameters, elastic modulus and viscosity. Since the process of rupture is different from that of stress-relaxation, the response of rupture may be different from that of stress-relaxation because in the rupture strength experiment, the sample is destroyed with the plunger. On the other hand, in the stress-relaxation experiment the sample is not destructed but deformed reversibly.

From the facts presented above, the rheological parameters of the unheated sample and the samples at 50°C or below differed from those of the samples heated at 60°C or above. This result indicates that the mechanisms of the stress-relaxation or

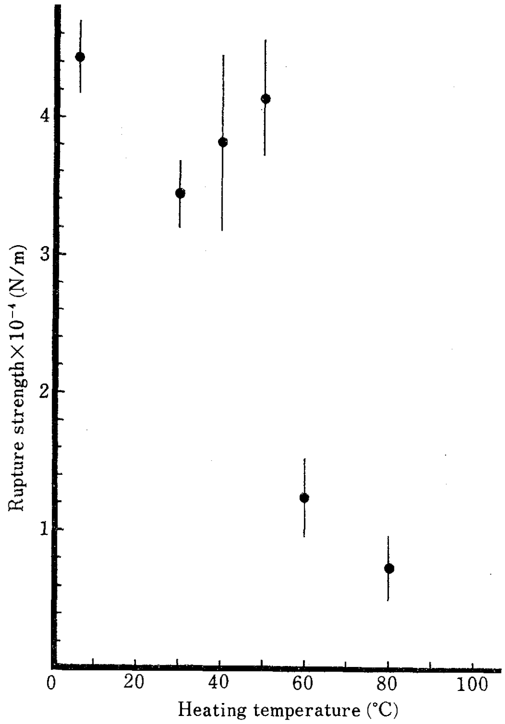

Fig. 4. The relationships between the rupture strength and the heating temperature. The heating was done for 30 min.

the rupture change as the heating temperature increases from 50°C to 60°C. The changes of the rheological parameters in the range from about 50°C to 60°C may be due to the structure change, *i.e.* the sample become shorten owing to heating at 60°C or above.

KIMURA *et al.*[5] have studied collagen of jellyfish. The jellyfish umberlla, containing about 70% protein on the basis of ash-free dry weight, was separated into two tissues, mesogloea and skin. The amino acid composition of mesogloea collagen is characterized by the high levels of hydroxylysine and its glycosides. The glycine content accounted for one-third of the total residues confirms the purity of this collagen preparation. Judging from its hydroxylysine content, approximately 80–90% of the total tissue protein was estimated to be collagn. In our thermal experiment, some endothermic reaction peaks were observed at the temperature from 53°C to 60°C in the differential scanning claorimetric thermogram of the whale jellyfish tissues. There are several reports indicated that collagen fibers shrink at around 60°C and that the collagen is transformed into water-soluble gelatin.[6] On the basis of these reports, it can be assumed that the shrinkage of collagen affects the unique texture of cooked jellyfish. The shrinkage of the main component of tissue is considered to result in the heterogeneous structure, the rough and fine parts in the structure. The shrinkage gives the sample fragility, that is, the rupture strength decreases at the shrinkaging temperature. On the other hand, the elastic modulus and viscosity increase with temperature, since the large stress comes from the high density part in the sample.

However, it is difficult to conclude that only collagen shrinkage affects the rheological parameters of cooked jellyfish, since the sample is already salted and pressed, and little is known about the composition except for collagen.

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