The Effects of Additives (Egg White and Soybean Protein) on the Rheological Properties of Kamaboko

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The effects of adding egg white and soybean protein on the rheological properties of kamaboko are examined by the stress-relaxation measurement, the jelly-strength measurement, and folding test. Although the additives increase the jelly-strength, elasticity, and viscosity, the effects are eliminated by adjusting the water-content to the value of the control sample which does not contain the additives. The additives may not contribute to the network structure of kamaboko. On the other hand, the rheological properties of kamaboko made of the different kinds of frozen surimi are also examined.

The rheology of kamaboko, a kind of fish-meat gel, has been studied by many investigators.¹⁻¹⁷⁾ It is clear that the rheological properties of kamaboko are essentially the rubber-like elasticity, which results mainly from the network structure of the protein chains.

Recently, egg white and soybean protein have been extensively used in kamaboko to strengthen its "ashi", a kind of rupture strength. Although the effects of adding these substances on the rupture strength of kamaboko have been reported,^{16,17)} the other rheological properties such as stress-relaxation time, elasticity, and viscosity have not yet been investigated extensively.

In this work, we examined the rheological properties of kamabokos which included egg white, and others which included soybean protein by stress-relaxation experiments, jelly-strength experiments, and folding test. On the other hand, we have prepared other kamaboko samples from the two kinds of frozen surimi, the excellent grade frozen surimi (the product of factory vessel) and the 2nd grade frozen surimi (the product of coastal factory). Then the rheological properties of the kamabokos were also compared and examined.

Experimentals

Materials

Samples were made from the excellent grade frozen surimi of Alaska pollack in the following

manner. The frozen surimi, the additive (0-30 wt%), water, and NaCl (3%) were completely ground at *ca.* 7°C by using a silent cutter (Hanaki Manufacturing Co., Ltd.). The paste was stuffed in poly(vinylidene chloride) casing (30 mm × 220 mm). Then it was heated for 120 min at 30°C, heated for 40 min at 60°C, and finally heated for 40 min at 90°C. Egg white, soybean protein, and potato starch were used as additives; the egg white powder used was a products of Taiyo Chem., Co., Ltd., and the soybean protein used was "Fujipro-620" which is a product of Ralston Purina Co., Ltd. The control sample, which does not include any additives, contains *ca.* 75% water. So the samples of which water content was adjusted to the values of the control were also prepared for the comparison.

On the other hand, another sample was made from the mixture of the excellent grade frozen surimi (the product of factory vessel) and the 2nd grade frozen surimi (the product of coastal factory) for the comparison, too.

Stress-Relaxation Experiments

The stress-relaxation experiments were carried out by using a REONER RE-3305 (Yamaden Co. Ltd.) at 20°C. The sample diameter and height were 30 mm and 20 mm, respectively. The stress-relaxation curves were obtained at a constant strain of 0.25 for 1 min. The equation of the stress-relaxation can be expressed approxi-

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mately as follows:

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

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

$$\tau_i = \eta_i / E_i. \quad (2)$$

The instantaneous compression modulus (E_0) is defined as follows:

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

The stress-relaxation curve obtained was analyzed by using the progressive approximate method.¹⁸⁾

Jelly-Strength Experiments

The jelly-strength (g·cm unit) was measured by using a Yamamoto Food Checker at 20°C as an usual manner; the ball plunger (diameter 5 mm) compressed the sample (diameter 30 mm and height 25 mm).

Folding Test

The folding test was done with a 3 mm thick sample. The results were expressed by the 1–10 rating system; the score "10" corresponds to "remarkably strong" and "1" corresponds to "paste-like or clay-like".

Results and Discussion

The stress-relaxation curve could be analyzed by the three trials of the progressive approximate method. This means that the n -value in eq. (1) is 3.

The results of the control, which does not include any additives, are as follows; $E_0 = 0.68 \times 10^6$ dyn/cm², $E_1 = 0.42 \times 10^6$ dyn/cm², $E_2 = 0.10 \times 10^6$ dyn/cm², $E_3 = 0.16 \times 10^6$ dyn/cm², $\tau_1 = 383$ s, $\tau_2 = 7.4$ s, $\tau_3 = 0.9$ s, $\eta_1 = 0.16 \times 10^9$ poise, $\eta_2 = 0.73 \times 10^6$ poise, and $\eta_3 = 0.15 \times 10^6$ poise.

Fig. 1 shows the relationships between the instantaneous elastic modulus (E_0) and the additive contents; the open symbols are referred to the samples of which water contents are not adjusted, and the closed symbols to the samples of which water contents are adjusted to the values of the control, ca. 75%. The E_0 -values of the samples of which water contents are not adjusted increase with the additive contents. The samples which

Fig. 1. The relationships between the instantaneous elastic modulus (E_0) and the additive contents: double circle, the value for the control; circle, that for the egg white; square, that for the soybean protein; triangle, that for starch. The closed symbols are referred to the samples of which water contents are adjusted to the values of the control.

Fig. 2. The relationships between the viscosity of the 1st element (η_1) and the additive contents: double circle, the value for the control; circle, that for the egg white; square, that for the soybean protein; triangle, that for starch. The closed symbols are referred to the samples of which water contents are adjusted to the values of the control.

included soybean protein could not be used in the experiment since the samples easily cracked under pressure. The results of the samples of which water contents are adjusted to the values of the control (ca. 75%) do not depend on both the kind of additive and its contents, and the E_0 -values are almost constant (ca. 0.7×10^6 dyn/cm²), which is

almost the same as that of the control. The other elastic modulus (E_1 , E_2 , E_3) show the same tendency as E_0 .

* Fig. 2 shows the relationships between the viscosity of the 1st element (η_1) and the additive contents. The other viscosities (η_2 , η_3) show the same tendency as η_1 . As shown in Fig. 2, the results of the viscosity are the same as those of elastic modulus. Namely, viscosity of the sample of which water contents are not adjusted increases with the increasing of the additive contents, while the viscosity of the water-contents adjusted sample does not depend on both the kind of additive and its contents, and also is almost the same as that of the control (0.16×10^9 poise).

These results suggest that egg white and soybean protein do not contribute to the network structure of kamaboko and behave as merely fillers as starch in kamaboko. This has already been made clear on starch.⁶⁾ Although these additives have been considered to raise the "ashi", a kind of rupture strength, of kamaboko,^{16,17)} the effect may not increase the crosslinks in network in kamaboko, but come from the fact that these substances absorb the water in the network structure of kamaboko. That is, the additive may be swollen with water in the network of protein chains and may exist as fillers in the structure.

The relaxation times do not change with the additive contents as shown in Fig. 3. It can be said from the results of relaxation time that the additives do not form the network structure in

Fig. 3. The relationships between the relaxation time of the 1st element (τ_1) and the additive contents: double circle, the value for the control; circle, that for the egg white; square, that for the soybean protein; triangle, that for starch. The closed symbols are referred to the samples of which water contents are adjusted to the values of the control.

Fig. 4. The relationships between the jelly-strength (J.S.) and the additive contents: double circle, the value for the control; circle, that for the egg white; square, that for the soybean protein; triangle, that for starch. The closed symbols are referred to the samples of which water contents are adjusted to the values of the control.

Table 1. Folding test score

Additive	Content (%)					
	0	5	10	15	20	30
Egg white	10	9	9	8	8	—
" + water	10	9	8	7	3	—
Starch	10	—	10	—	10	10
" + water	10	—	10	—	10	9
Soybean + water	10	9	9	9	—	—

kamaboko, too. Namely, the relaxation mechanism is considered to come from the network structure as a rubber-like structure. Then, from the fact that the relaxation times do not depend on both the kind of additive and its contents, the network structure of kamaboko consists of the fish protein chain in frozen surimi, and the egg white protein chain and the soybean protein chain do not participate in the network.

Fig. 4 shows the additive contents dependence on the jelly-strength. As pointed out earlier,^{16,17)} the jelly-strength increased with the egg white contents. However, once water is added to the sample up to the water contents of the control, the jelly-strength decreases with the additive contents. The results may support the statement that the additives do not contribute to the network of kamaboko and that they behave as fillers. The increase in jelly-strength of the sample of which water contents are not adjusted can be attributed to the loss of water in the network by the absorption effect of

Fig. 5. The effects of adding the 2nd grade frozen surimi on E_0 (open circle), η_1 (open triangle), and τ_1 (open square).

Fig. 6. The effects of adding the 2nd grade frozen surimi on J.S. (open circle) and the sensory test score (closed circle).

the additives.

Table 1 shows the results of the folding test. In general, the samples can be cracked easily when the additive contents are increased.

The results of the addition of the 2nd grade frozen surimi are shown in Fig. 5. The rheological parameters (E_0 , η_1 , τ_1) decrease linearly with the 2nd grade frozen surimi contents. Other parameters have the same tendency as shown in Fig. 5. This means that the crosslink density in the network structure of kamaboko decreases by adding the 2nd grade frozen surimi, although the protein chains from the 2nd grade frozen surimi form the network structure slightly. The fish protein loses

the ability of forming network structure with the decrease of freshness. In other words, it can be considered that the large parts of the fish proteins in the 2nd grade frozen surimi have denatured. The same tendencies are shown in Fig. 6; the jelly-strength and the score of the folding test decrease with the increasing of the 2nd grade frozen surimi contents.

The correspondence of each rheological parameters to the structure and composition of kamaboko must be made clear in future.

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