Rheological properties of fish paste products sold on the market in Japan

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Aiming at good understanding the properties of the recent fish paste products sold on the market in Japan and making a basis for designing foods for the elderly (so-called elderly foods), rheological properties of typical fish paste products were investigated and those with elastic properties were compared with results obtained from fish-meat-based elderly food. According to the Ministry of Health, Labor and Welfare of Japan, the gel strength of elderly foods are should be lower than 2×10^4 N/m^2 for senior citizens who have chewing and swallowing problems. In this report, it was shown that elderly foods, which indicated "Nursing foods" or "Medicare foods," bought from the market had lower breaking gel strength (GS value) than 1.5×10^4 N/m^2. However, various traditional and common fish paste (kamaboko) showed high GS value above 4×10^4 N/m^2. The average GS value of them was 10 times higher than that designed for elderly foods. This fact suggests the reasons for limited consumption for the elderly with chewing problems. While fish pastes combined with egg yolks or soybean curd showed lower GS values than common kamaboko level. It was supposed that elderly people select those soften fish paste product that applying with non fish additives into the fish paste. As the population ages, it is necessary to design and to produce more acceptable fish products for the elderly without a loss of desirable flavor and texture.

Key Words：fish paste products, elderly food, gel strength, food designing

Introduction

Currently, the world's population of seniors aged 60 years or over is growing at a considerably faster rate of 2.44% per year than that of the total population of 0.7% per year[1]. In the near future, the difference between the two rates is expected to become even lager as the baby boom generation starts reaching older ages. In Japan, the population of elder people over 65 year-old in 2011 is already 23.3% of the total population[2], making Japan one of the "greyest" countries on the Earth. It is also projected that the percentage will increase to 39.6% by 2050[3].

As the world's senior population grows rapidly, great attention is being paid to the health care of seniors, and it has created a strong demand for foods for seniors, because seniors usually have chewing and swallowing disfunction[4], which leads to limited food choice, and may cause anxiety or panic during mealtimes. Research on elderly foods concerning the food preference of Japanese elderly people, like the effect of size, shape and mouthful amount of foods on the mastication properties[5] is already reported. Therefore, food with an appropriate texture should be tailored to the elderly. Thus the Japanese Ministry of Health, Labor and Welfare has indicated "less than 5×10^4 N/m^2 of chewing force" as the standard chewing force for foods for senior citizens who have chewing and swallowing problems[6]. According to this, Nursing foods and many Medicare foods are now being developed on the market.

Marine fish contributed a lot to the diet, both for the poor and for the wealthy, due to the high-qualified protein value, and rich triglycerides consisting of unsaturated fatty acids[7], such as omega-3 polyunsaturated fatty acids, which are vital for normal metabolism and cannot be synthesized by the human body. And it also provides a large variety of mineral macro- and micro-elements like as calcium, magnesium, phosphorus, sodium and potassium[8]. Other important microelements like iron, zinc, copper and manganese are also included[8,9]. There is a growing awareness of the beneficial role of fish and other marine foods in human

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nutrition. Thus leading to a large and growing demand for fish and marine shellfish as a cheap source of valuable nutrients for the people in need, especially for the elderly people.

Fish paste, in which various fish are pureed, combined with salt and other additives such as starch, egg white and monosodium glutamate (MSG), formed into distinctive loaves, and by heat-cooking, is called kamaboko and widely consumed in Japan. There are wide varieties of fish paste products by different heat-cooking treatments, such as steaming, broiling, boiling and frying kamaboko, which are called Mushi Kamaboko (i.e., Itatsuke Kamaboko), Yaki Kamaboko (i.e., Chikuwa), Yude Kamaboko (Hanpen and Tsumire), and Age Kamaboko (i.e., Satsuma-age), respectively in Japan. Gel strength is critical to the texture of kamaboko, and traditionally, mostly determines the quality of kamaboko. Steamed and broiled fish pastes usually have strong texture, while boiled and fried ones have a comparatively weaker texture. However, common fish paste with strong gel strength can be a big problem for elderly people. Modifying the gel strength of fish paste product is essential for developing food intended for the elderly's chewing and swallowing ability. Although a few Japanese food companies are already developing some foods for the elderly (so-called "elderly foods"), the specially designed food for the elderly is still very limited and usually expensive.

In this study, we examined the rheological properties of commercial fish pastes sold on the Nagasaki city market and/or of commercial fish-based elderly foods on the Japanese market. The study will help to clarify our understanding of the rheological characters of the now-available fish paste products on the market, and broaden the food market aimed at the elderly.

Materials and Methods

Samples

For traditional commercial fish pastes, 7 samples of Chikuwa (broiled kamaboko), 7 of Itatsuke Kamaboko (steamed kamaboko), 7 Age Kamabokos (fried kamaboko), 2 Yude Kamabokos (boiled kamaboko, 1 Hanpen and 1 Tsumire) were collected from the market in Nagasaki City. Additionally, 1 Tofu Kamaboko and 1 Datemaki were collected. Seven Fish based-Elderly foods, which indicated 'Nursing food' or 'Medicare food' for elderly people, were collected from the market in Japan. And also, 1 agar-based food was added for comparison. These samples were listed in Table 1.

Table 1 List of collected commercial fish paste products.

Sample	Ingredient (Fish name)	Product name	Producer
C-1	Lizardfish, Pollack	Chikuwa	A
C-2	Flying fish, Alaska Pollack	Chikuwa	B
C-3	Tilefish, Alaska Pollack	Chikuwa	B
C-4	Pollack, Lizardfish, Gurn-ard	Chikuwa	C
C-5	Pike eel, Golden tread, Pollack	Chikuwa	D
C-6	Sea bream, Pollack	Chikuwa	E
C-7	Sardine, Chub mackerel	Chikuwa	E
I-1	Lizardfish, Sea bream, Pollack	Itastuke kamaboko	A
I-2	Flying fish, Alaska Pollack	Itastuke kamaboko	B
I-3	Tilefish, Alaska Pollack	Itastuke kamaboko	B
I-4	Croaker, Pollack, Lizardfish	Itastuke kamaboko	C
I-5	Sardine, Pollack	Itastuke kamaboko	C
I-6	Pollack, Lizardfish, Croaker	Itastuke kamaboko	F
I-7	Sea bream, Pollack	Itastuke kamaboko	G
F-1	Lizard fish, Alaska Pollack	Fried kamaboko	B
F-2	Sardine, Alaska Pollack	Fried kamaboko	B
F-3	Jack mackerel, Alaska Pollack	Fried kamaboko	B
F-4	Flying fish, Jack mackerel, Lizardfish	Fried kamaboko	E
F-5	Sardine, Jack mackerel, Lizardfish	Fried kamaboko	E
F-6	Jack mackerel, Lizardfish	Fried kamaboko	E
F-7	Lizard fish, Pollack	Fried kamaboko	E
B-1	Shark	Hanpen	C
B-2	Sardine, Pollack	Boiled kamaboko	C
M-1	Alaska Pollack, Lizardfish	Datemaki	B
M-2	Soybean curd, Pollack	Tofu kamaboko	H
S-1	Banded reef-cod	Elderly food	I
S-2	Hake	Elderly food	I
S-3	Salmon	Elderly food	I
S-4	Pollack	Elderly food	J
S-5	Chub mackerel	Elderly food	I
S-6	Japanese Spanish mackerel	Elderly food	I
S-7	Crimson sea bream	Elderly food	K

Texture analysis

Textural analysis of fish pastes was performed using a rheometer (FUDOH, NRM-2010J) to measure breaking gel-strength and cleavage. Samples were equilibrated and tested under room temperature. 5 to 10 oval-shaped samples with 5 mm of thickness, 5 mm of width and 16.8 mm of internal diameter were prepared. The sample was elongated by a pair of L-shape stainless plungers, and the elongation speed of sample was 60 mm/min. The GS value was calculated as follows:

$$GS = \frac{\text{Breaking force (N)}}{\text{Area of broken cross} - \text{section (m}^2\text{)}}$$

Determination of moisture content

Moisture content was measured using a moisture analyzer (Sartorius, MA-45). About 2 g of sample were prepared, and chopped into small pieces, which were less than 2 mm of length and width. Then immediately, the sample was placed onto the stage of the analyzer and heated at 105 ℃.

Determination of water holding capacity

Measurement of expressible moisture in fish has been used to estimate the water holding capacity (WHC)[10]. About 1 g of sample was cut into a thickness of 5 mm, placed between two pieces of filter papers. Ten kg/cm^2 of pressure was placed at the top and held for 2 minutes. The sample was then removed from the papers and the expressible water that was absorbed into the paper was weighted. Different expressible moisture suggests differences in water holding capacity of the gel network[11]. The expressible water content and the WHC were calculated as follows:

$$WHC = \frac{moisture\,(\%) - \exp\,(\%)}{moisture\,(\%)}$$

$$here: \exp\,(\%) = \frac{expressible\ water\,(g)}{sample\ weight\,(g)} \times 100$$

Statistical analysis

To calculate the standard error and the correlation coefficient (R, significance level $p<0.05$), statistical analysis was performed using SigmaPlot 12.0 and Microsoft Excel 2010 software.

Result and Discussion

Texture characteristics of fish pastes and elderly foods

Traditionally, there is no doubt that gel strength is of primary interest in fish paste production in Japan. The breaking strength has been used in the fish paste industry as an indicator to measure the quality of fish paste[12]. Tested fish pastes of various fish species by different processing methods shown in Table 1 had varying gel strength and deformation as in Fig. 1. Average gel strength of traditional fish pastes and elderly foods were compared in Table 2. The average GS value of elderly foods was 0.58×10^4 N/m^2. For common kamaboko, the average GS value was in the order of Chikuwa, fried kamaboko, Itatsuke kamaboko, boiled kamaboko, which was 13.2, 12.9, 11.1 and 7.4 times against the average of GS value for elderly foods, respectively. According to the Ministry of Health, Labor and Welfare, " less than 5×10^4 N/m^2 " is the standard level for foods for senior citizens with chewing and swallowing problems[6]. Almost all GS value levels of traditional kamabokos were higher than the standard. However, some of boiled kamaboko such as Tsumire (GS value; 4.3×10^4 N/m^2) used here, Hanpen (; 3.6×10^4 N/m^2), Tofu kamaboko (; 4.2×10^4 N/m^2) and Datemaki (; 3.1×10^4 N/m^2) showed intermediate values between common kamabokos and elderly foods, and they may effectively meet the Japanese standard for elderly foods, whereas the GS value of Tofu kamaboko and Datemaki were 7.2, 5.3 times of the elderly foods, respectively. Those GS values were similar to agar-based food (GS value; 2.14×10^4 N/m^2). As in Fig. 1, the strain of elderly foods were very small, the average value was only 5.11 mm, which was even smaller than that of Datemaki, Tofu kamaboko and boiled fish pastes like Hanpen and Tsumire. Strains of other kamaboko were all more than 20 mm. The strain of agar-based food was 4.4 mm. Those results indicate that elderly food with weak breaking force had small strain.

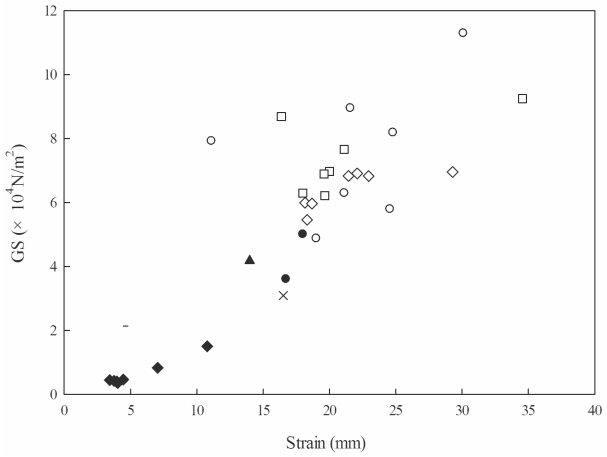

Fig.1 Gel strength and strain of various commercial fish paste products.
Symbols: Itatsuke kamaboko (◇), Chikuwa (○), Fried kamaboko (□), Boiled kamaboko (●), Datemaki (×), Tofu kamaboko (▲), Elderly food (◆), and Agar (–).

Table 2 Gel strength and Young's Modulus of commercial fish paste products.

Product	Range of GS-value (10^4 N/m^2)	Average of GS-value (10^4 N/m^2)	Average of Young's Modulus (MPa)	n
Chikuwa	4.87～11.29	7.61±2.01	0.06±0.02	7
Itatsuke kamaboko	5.46 ～6.96	6.42±0.56	0.05±0.01	7
Fried kamaboko	6.22 ～9.25	7.43±1.08	0.06±0.01	7
Boiled kamaboko	3.60 ～5.00	4.30±0.89	0.042±0.07	2
Elderly food	0.30～1.50	0.58±0.29	0.02±0.01	7

Average value was shown with standard error.
n; number of samples

Elderly food had the low levels of Young's Modulus (Fig. 2). The average value (Table 2) was 0.02 MPa, while for common kamaboko, the average value of Chikuwa and fried kamaboko had the highest Young's Modulus (0.06 MPa,). However, Datemaki (0.03 MPa) tested here, was similar with the value of some of elderly foods. This further demonstrates the soft texture of elderly foods. Also, Fig. 2 showed Young's Modulus of all kinds of kamaboko and elderly foods which increased with the increase in GS value.

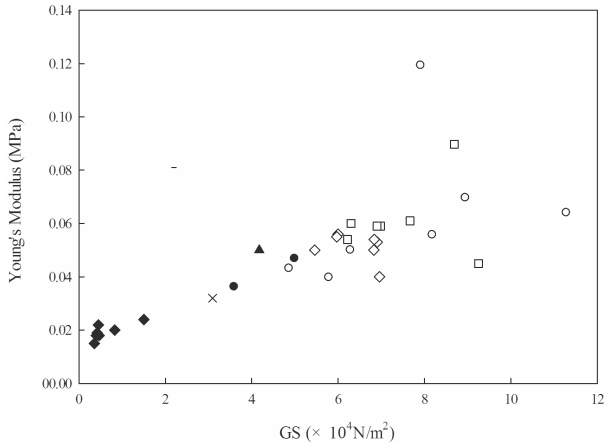

Fig.2 Young's Modulus and gel strength of various commercial fish paste products.
Symbols: Itatsuke kamaboko (◇), Chikuwa (○), Fried kamaboko (□), Boiled kamaboko (●), Datemaki (×), Tofu kamaboko (▲), Elderly food (◆), and Agar (–).

Moisture of fish pastes and elderly foods

The moisture content of elderly foods ranged widely from 40.68% to 72.76%, with average moisture being 56.81%. Common kamaboko had higher moisture, all more than 60%, with average moisture content of 68%. During eating, we swallow when the total amount of the water in food and saliva reaches a certain value, and times of chewing depends on the water content in the food[13]. For this reason, if the elderly food contains too much water, the elderly are likely to directly swallow without chewing and which may cause choking. So scientists studied certain elderly foods to better understand to the characteristics of gel texture and frequency related to chewing and swallowing condition, aiming to design elderly food that will not cause choking and swallowing problems[14]. Fig. 3 shows the relation between the GS value and WHC of analyzed samples. For water holding capacity, the value of elderly foods ranged from 2.5 to 51, with an average value of 42. The average WHC of common kamaboko was almost twice the value for elderly foods. Further, the GS and WHC data of elderly foods had a correlation coefficient of R = 0.6879,

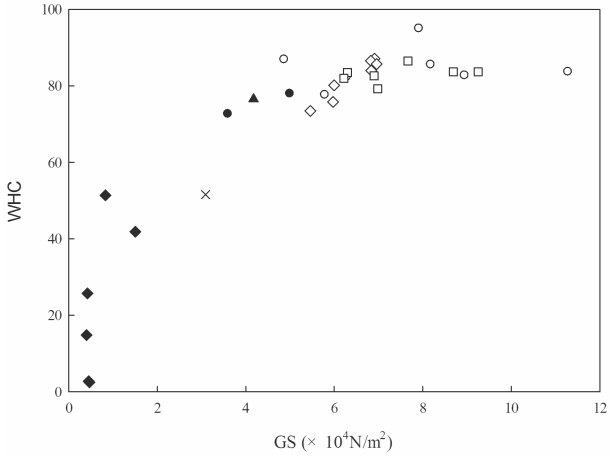

Fig.3 Water holding capacity and gel strength of various commercial fish paste products.
Symbols: Itatsuke kamaboko (◇), Chikuwa (○), Fried kamaboko (□), Boiled kamaboko (●), Datemaki (×), Tofu kamaboko (▲), and Elderly food (◆).

while GS of common kamaboko was proportional to WHC as shown in Fig. 3. Itatsuke kamaboko showed high correlation coefficients (R = 0.9613). It was noted that comparing common kamabokos with Tofu kamaboko, WHC level was similar to each other. While Datemaki had lower WHC level, similar to elderly foods.

The character of fish-meat based elderly foods (sold for 'Nursing food' or 'Medicare food') can be summarized as having lower gel strength, lower elasticity (soft texture) and smaller water holding capacity. Benjackul found that proteolysis resulted in the degradation of myofibrils to smaller peptides, leading to a weakened gel matrix, which could not hold water effectively[15]. However, according to the SDS-PAGE analysis, the protein content of the 200 kDa component, associated with the myosin heavy chain, in elderly foods tested here, was about 45% of the total protein content (data not shown). Therefore, those elderly foods were not softened by protein digestion. Tested elderly foods do not show how to prepare their soft texture. It is necessary to design and to produce fish products that are acceptable for the elderly without a loss of desirable flavor and texture, and a loss of nutritional value of protein. For further study, it is important to investigate new ways of designing more acceptable fish products for the elderly. Ichikawa *et.al.* reported that the addition of small amounts of triglyceride into fish myofibrils decreased the gel strength of the heat-set gel effectively[16]. In this case, it is possible to reduce the gel strength of fish paste products without protein dilution and degradation of actomyosin. It is not clear if the tested elderly foods contained such triglycerides or not. And also, egg white

are often used to increase gel strength and to give a whiter and glossier appearance to the gel[17], whereas for fish paste production, the effect of egg yolks has not been reported. It was suggested that egg yolks mainly contributes to the soft texture of Datemaki. Obviously, addition of egg yolks might be an optional way for designing elderly foods.

Mastication and chewing is the process by which food is crushed and ground by teeth. It is the first step of digestion. Eating well with a weak muscle power and/or eating well with only a few teeth are indispensable matters for elderly people. In this study, it was shown that fish paste products made from varieties of processing methods and of fish species with different rheological properties were available on the market. Generally, the properties of fish pastes depended on fish species and method of heat-cooking[11]. However, the rheological properties of elderly foods on the market were very different from many traditional fish pastes, GS values of elderly foods surveyed in this study were mostly under 2×10^4 N/m^2, which is the Japanese standard level for elderly people with chewing and swallowing difficulties and just eating by the tongue[6]. Another kind of fish paste product studied here, that had soybean curd or egg yolks applied in the processing recipe had a gel strength under 5×10^4 N/m^2. This is almost appropriate for elderly foods. It suggests commercial fish pastes that consumable for elder people who have a chewing problem were pertly available from market now. Those elderly people may select such soften fish paste that combined with non-fish additives such as egg yolks or soybean curd. In addition, some common fish paste products such as Hanpen and Tsumire also may meet the requirement of soft texture. These are 'intermediate-texture-foods' between well-gelled common Japanese fish pastes (kamaboko) and 'Nursing or Medicare foods' for elder persons. Nevertheless, food-package designs do not provide information on texture. It may prevent elder people from choosing food and enjoying a high quality of life. Therefore, if the description of each texture profile is quantified, and provided on the package, it can make the elderly better able to buy what they need. Rheological information like those limited fish products aimed at the elderly consumption should be induced on food packages in our society, both in terms of nutrient and organoleptic properties.

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日本で市販されている魚肉練り製品のレオロジー特性

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魚肉を原料とした市販練り製品25品目の破断強度，縦弾性係数，保水力の分析を行なって分布を明らかにし，これらを咀嚼能力が低下した高齢者に適応させた市販介護食7品目の特性と比較した。その結果，GS値(10^4 N/m^2)の分布と平均値は，ちくわ；4.87〜11.29, 7.61±2.01，板付かまぼこ: 5.46〜6.96, 6.42±0.56, 揚げかまぼこ; 6.22〜9.25, 7.43±1.08，蒸しかまぼこ; 3.60〜5.00, 4.30±0.89だったのに対し，介護食では0.30〜1.50, 0.58±0.29とワンオーダー異なっており，著しい差異があった。 また，豆腐かまぼこや伊達巻は，それらの差を埋めるような中間領域の物性を示す事も分かった。高齢者の購入選択指標として，市販製品に弾力情報を表示することが求められる。