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Original article

Tribology of agar and fish meat gel

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Introduction

The aged society has arrived in Japan. However, many kinds of sea food, e.g. algae, Kamaboko, grilled fish, and etc., are difficult for elderly parsons to masticate and swallow. Though the mastication indicator of foods for elderly persons is established in Japan, e.g. Japanese Agricultural Standards [1], swallowing one [2] cannot provide the information whether they can swallow or not. Recently, tribological studies of food for smooth palate feeling have started [e.g. 3,4]. We are considering that tribology may be able to characterize the swallowing behavior. In this study, to establish the methods of tribological measurement and to characterize tribological properties of sea foods were aimed.

Materials and methods

Fish-meat gel and agar gel were selected as samples in this study. Fish-meat gel samples were commercial Kamaboko gels (Odawarakko, Suzuhiro Co., Ltd., Japan). 1.6 % (w/v) agar gels containing 0.4% milk as a white coloring agent were prepared. Agar powder (Kanten cook, Ina Food Industry Co., Ltd., Japan) was dissolved in boiling water containing milk. Then, the solution was cooled at 5°C for 24 hours to form gel. Both gels were cut into 15 mm cubes.

Water contents of sample gels were measured according to AOAC [5].

Texture profile analysis (TPA) tests were performed with a tensipressor (TTP-50BXII, Taketomo Electric Inc., Tokyo, Japan) at 25°C. The following conditions were selected for TPA tests: cylindrical plunger with a diameter of 6 mm, compression speed 10 mm/s, and clearance 4.5 mm. Sample gels were compressed two times. TPA parameters, which are hardness, cohesiveness, stickiness, springiness, adhesiveness, fracturability, and gumminess, were obtained by analyzing the stress-strain curves.

Mastication behavior was observed to consider the sample condition for tribological measurement. Nineteen healthy subjects in their 20's participated in this study. Participants did not have any disturbances in mastication or deglutition. Written informed consent was obtained from each subject after explanation of the aims and methodology of the study. All study protocols were approved by the ethics committee at Tokyo University of Marine Science and Technology. Test was performed at around 3 p.m. Participants were subjected to three tests for each gel. First, participants ate a 15 mm-cube gel. The behavior was recorded by a video camera. The motion of their jaw was counted as a chewing time by watching the video. Second, they masticated another gel, and then spit it into a clean glass container just before they wanted to swallow it. Then, amount of saliva was determined by weighing. Third, they masticated and spit one more gel into another container, then, they rinsed their mouth by 15 mL water and spit the water into the same container. The bolus in the container was recorded as an 800dpi image file using a scanner to count the particle number and size by image analysis. Participants rinsed their mouth between the three tests. The software of image analysis, Image J (NIH, USA) was used.

Tribological tests were performed using a rotational rheometer (HAAKE MARS II, Thermo Fisher Scientific Inc., Newington, Germany) with tribology cell. The tribology cell has a silicone ball rotating on the silicone plate having a human skin hardness of 10° in rubber hardness. The gap between the ball and the plate was set to 0.5 mm. Chopped gel having the same particle size distribution as the bolus and mixed with the same amount of 1% thickening agent (Toromi Smile Clear Beverage Thickener, Healthy Food Co., Ltd., Chiba, Japan) as saliva in the bolus was smeared on the plate. All tests were performed by applying a normal load of 1 N and rotational speed from 0.1 to 35 s^{-1} at 37°C.

Static frictional coefficients were obtained using a portable friction meter (Muse: type 94i-II, SHINTO Scientific Co., Ltd., Tokyo, Japan) with a rubber slider as a detector. The slider was attached on the 10^{o}-hardness silicone plate smeared with chopped gels at 37°C.

Results and discussion

Water contents of agar and fish-meat gels were 97.8 % and 70.6 %, respectively. TPA parameters showed that

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Table 1. TPA parameters of sample gels

	Hardness [$\times 10^5$ Pa]	Cohesiveness	Stickiness [$\times 10^3$ Pa]	Springiness	Adhesiveness [$\times 10^2$ J/m^3]	Fracturability [$\times 10^5$ Pa]	Gumminess [$\times 10^4$ Pa]
Agar gel	1.76 ± 0.05	0.21 ± 0.01	1.73 ± 0.00	0.95 ± 0.02	0.72 ± 0.22	1.03 ± 0.76	1.47 ± 0.44
Fish-meat gel	1.94 ± 0.08	0.62 ± 0.07	6.16 ± 2.53	0.93 ± 0.02	8.16 ± 6.76	1.94 ± 0.08	1.13 ± 0.20

$n = 10$

Table 2. Mastication parameters of 15 mm cube gels and static friction coefficients of chopped gels

	Chewing number	Chewing time [s]	Chewing velocity [s^{-1}]	Saliva [g]	Static friction coefficients [$\times 10^{-3}$]
Agar gel	43.1 ± 18.7	26.7 ± 11.7	1.6 ± 0.3	1.3 ± 0.8	3.9 ± 2.0
Fish-meat gel	38.8 ± 9.2	24.8 ± 5.7	1.6 ± 0.2	1.7 ± 1.0	6.5 ± 1.1
n	19	19	19	19	10

these sample gels had different texture each other (Table 1).

Table 2 showed the mastication parameters. Fish-meat gel tended to be more salivation during mastication than agar gel even though chewing number and time of agar gel tended to be higher values than fish-meat gel. Perhaps, added salt in fish-meat gel promoted to salivate. Bolus of fish-meat gel contained larger particles than that of agar gel (Fig. 1). It will be possible that higher cohesiveness, stickiness, and adhesiveness of fish-meat gel will lead to lager particle size of the bolus.

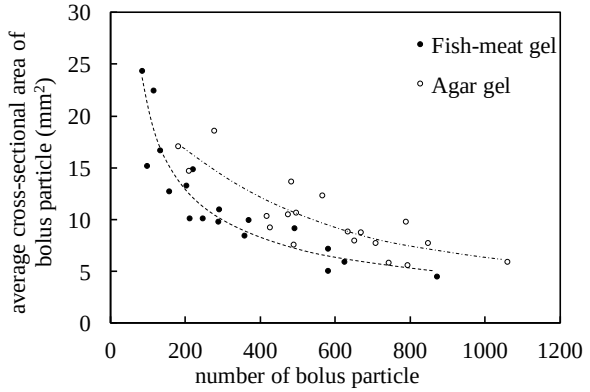

Fig. 1. Size distribution of bolus particle in the mouth.

Samples for tribological measurement were prepared by cut gels with a knife to have the same particle size distribution of bolus and by adding thickening agents having the same rate of saliva in bolus to cut gels. Frictional force of samples showed typical Stribeck curves [6]. These Stribeck curves could be divided into three different regimes namely the boundary, mixed and hydrodynamic regimes. Although the static friction coefficient of chopped fish-meat gel was larger than that of agar gel (Table 2), fish-meat gel was more lubricity than agar gel in the dynamic measurement (Fig. 2). Because large and high cohesiveness particles of fish-meat gel separated from the rubber plate during the measurement, lubricity between the sensor and the thickening agent containing small amount of fish-meat gel particles was detected. On the other hand, agar gel particles crumbled without separating from it during the measurement. These phenomena could be reflected real person having difficulty in swallowing. In the case of fish-meat gel, if they cannot move their own jaw well, bolus in the mouth will be separate into solid and liquid components. Therefore, fish-meat gel could be difficult for them to swallow and remaining in their mouth.

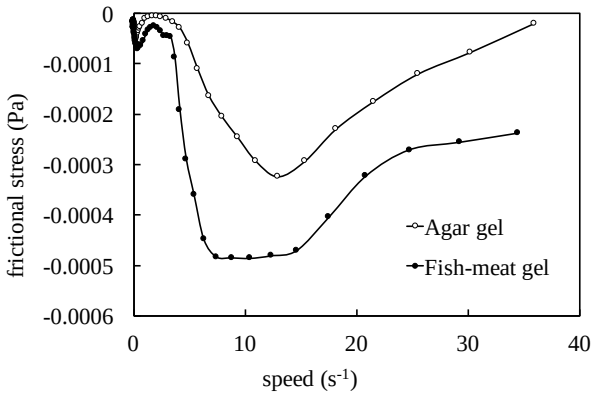

Fig. 2. Friction curves for chopped agar and fish-meat gels mixing thickening agent instead of saliva at 37 ºC.

Acknowledgements

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