Effects of soaking conditions on the texture of dried sea cucumber

TOSHIKO FUKUNAGA,1* MISUZU MATSUMOTO,2 TOMOKO MURAKAMI3 AND KEIKO HATAE4

1Ueno Gakuen University Junior College Department, Soka, Saitama 340-0048, 2Aoyama Gakuin Women's Junior College, Shibuya, Tokyo 150-8366, 3Hokkaido University of Education, Kushiro, Hokkaido 085-8580 and 4Faculty of Human Life and Environment Sciences, Ochanomizu University, Bunkyo, Tokyo 112-8610, Japan

ABSTRACT: Dried sea cucumber must first be soaked in water, then heated and finally left at 20°C for 24 h, this procedure being repeated several times in preparation for cooking. In the case of dried sea cucumber soaked in distilled water, it gradually increased in weight. After full-scale soaking twice, its weight increased to 7.6-fold the original weight, which softened it thoroughly. The water content after this soaking process was 94.5%, which is almost the same as that of raw sea cucumber. During the soaking process, not only was water absorbed, but components of the ingredients of sea cucumber were eluted into the soaking water. Among these components, ash was eluted fastest, next was glycosaminoglycan and last was collagen. In addition to distilled water, rice-washing water, a coarse-tea-infused solution and a potassium carbonate solution were used as the soaking solutions. Sea cucumber absorbed water and swelled in the potassium carbonate solution faster than in the other three solutions. Textural measurements and a sensory evaluation clarified that the softest sea cucumber resulted from the rice-washing water, and the hardest sea cucumber from the coarse tea.

KEY WORDS: collagen, glycosaminoglycan, 'kansui', potassium carbonate solution, sea cucumber.

INTRODUCTION

Dried sea cucumber (Iriko or Kinko in Japanese) is produced by removing the intestines of Manamako Stichopus japonicus, boiling it in sea water and then drying it in the sun. The desirability of dried sea cucumber does not come from its flavors but from its unique texture, which is sleek, soft and appropriately elastic. It is used as a delicacy in stews and stir-fried dishes in Japan, China, Taiwan, the Korean peninsula and Indonesia. Dried sea cucumber must be soaked in preparation for cooking. Its texture depends on the soaking method. It has to be heated in the soaking solution over a low flame and left to cool. The solution has to be changed and this process repeated several times. The soaking solutions suggested in cookery books are rice-washing water, water with straw, coarse-tea-infused solution and potassium carbonate solution.1–6 The relationship between the soaking method and the texture of soaked sea cucumber has rarely been studied.7 An experiment was therefore performed to elucidate the effect of soaking conditions on the texture of dried sea cucumber based on textural measurements and a sensory evaluation.

MATERIALS AND METHODS

Materials

The dried sea cucumber was Manamako Stichopus japonicus, which had been bred in Hokkaido and bought in Taipei. Each specimen weighed 10.49 ± 1.29 g.

Soaking conditions

The dried sea cucumber specimens were soaked in distilled water at 20°C for 24 h, heated for 30 min at 92°C and then left in the soaking water at 20°C for 24 h. Each specimen was split, and waste water in the intestines and the abdominal muscle
was removed. The cleaned specimen was boiled for 30 min at 92°C as full-scale boiling. Four kinds of solution were used for this full-scale boiling: (i) distilled water; (ii) rice-washing water obtained from the surface of 1 L of water in which 100 g of rice had been soaked for 30 min; (iii) tea obtained from the surface of 1 L of boiled water in which 20 g of coarse tea leaves had been infused for 5 min; and (iv) 0.2% potassium carbonate solution. After heating, each specimen was left at 20°C for 24 h to soak. This full-scale boiling and soaking process were repeated twice to produce soaked sea cucumber, except for the potassium carbonate solution for which the process was conducted only once.

Rate of weight increase
The rate of weight increase of a specimen after each step of soaking compared with the weight of the original dried specimen was measured.

Proximate analysis
The contents of water and ash were determined based on conventional methods.

Collagen content
Collagen in the specimen was measured as described previously. The specimen was homogenized with the same quantity of water and centrifuged at 9000 × g for 10 min. The collagen in the supernatant was defined as water-soluble collagen.

Glycosaminoglycan content
Glycosaminoglycan was extracted from a specimen according to Kariya et al. Uronic acid contained in the glycosaminoglycan was measured by the carbazole method, the quantity of glycosaminoglycan then being calculated by multiplying the quantity of uronic acid by 3.0.

Physical properties
The penetration was measured with a penetration test machine (Nihon Oil and Fats Test Machine Industry AN-201; Zenken GTX, Tokyo, Japan) according to JIS K2207. Hardness and cohesiveness were measured with a texturometer (Zenken GTX-II); the plunger was a Rusaito type of 18 mm in diameter, 4 mm in clearance, and a voltage setting of 1. The specimen size was 10 × 10 × 10 mm. The breaking strength (g) and breaking strain (%) were measured with a creep meter (Yamaden RE3305); the plunger was wedge-shaped, the load cell was 2 kg, the compression speed was 0.5 mm/s, the maximum strain was 90% of the height of a specimen, and the size of a specimen was 10 × 10 × 20 mm. The penetration test was performed only on the sea cucumber specimen that had been soaked in distilled water.

Sensory evaluation
Sea cucumber specimens, which had been soaked under the different conditions, were cut into samples of 2 cm in width and 4 cm in length and cooked, before being coated in starch made from soy sauce, sake, sugar and dogtooth violet. The sensory evaluation was performed on the specimens that had been soaked in distilled water with respect to the appearance, flavor, texture and seven parameters related to the overall palatability, according to the paired difference test and the paired preference test. The panel consisted of 13 students of the Cookery Science Department at Ochanomizu University.

Statistical analysis
The tests on composition of sea cucumber were carried out in triplicate and on physical properties five times. The experimental results were expressed as average ± standard deviation. The experimental data were processed by analysis of variance.

RESULTS AND DISCUSSION
Changes in component composition and textural characteristics of the sea cucumber samples soaked in distilled water
Dried sea cucumber samples were soaked in distilled water. The changes in the rate of weight increase, component composition and penetration are shown on Table 1. The rate of weight increase gradually increased with soaking treatment: it was, 2.2 times that of the original specimen, 3.8 times after soaking, after preparatory boiling 5.8 times after the first full-scale boiling, and 7.6 times after the second full-scale boiling. It is apparent that the dried sea cucumber samples gradually absorbed water and swelled during the
soaking process. The standard deviation for the rate of weight increase after the first full-scale boiling varied widely according to the specimen; however, the standard deviation for the rate of weight increase after the second full-scale boiling varied much less. It can therefore be said that full-scale boiling twice standardized the water absorption and swelling of the sea cucumber samples, regardless of the type of boiling solution.

The principal ingredient of the body wall of sea cucumber is collagen. It has been reported that acid mucopolysaccharide and positive ions are responsible for the crunchy texture of sea cucumber. The percentage change of these components during the soaking process was therefore examined. The present study showed the following percentage components: 16.0% water, 25.5% collagen, 1.83% glycosaminoglycan and 10.6% ash. It is considered that such a high proportion of ash resulted from the seawater in which the sea cucumber had been boiled during the process of producing dried sea cucumber. Collagen was the principal component of sea cucumber, representing a quarter of the weight. The proportion of water in sea cucumber initially increased rapidly during soaking to 70.4% and then gradually increased during the later process. After the second full-scale boiling, the proportion of water had increased to 94.5%, which is almost the same as that of raw sea cucumber. In contrast, collagen, glycosaminoglycan and ash decreased as the water content increased. However, the rate of decrease of these components was not stable.

In order to identify the elution of these components during the soaking process, each component contained in the original dried specimen of sea cucumber was set at 100, and the quantity of each component during the soaking process was calculated. The change in content of each component is shown in Fig. 1. Ash comprised approximately 50% after soaking in water, and then dropped to approximately 20% after the second full-scale boiling. It can therefore be concluded that the ash was eluted rapidly during the water-soaking process. The largest component of the ash was sodium, from which it can be concluded that the sodium in seawater was absorbed by the body surface of the sea cucumber during the production of dried sea cucumber and then eluted in the early stage of the soaking process. Glycosaminoglycan decreased to approximately 40% after the second full-scale boiling, indicating that it gradually decreased during the water-soaking process. The elution of collagen showed on the increasing trend during the water-soaking process; however, after the second full-scale boiling, the collagen content decreased to approximately 70% of that contained in the original dried specimen. It can be concluded that sea cucumber absorbed water, and components in the body wall were eluted, the elution speed of ash being the fastest, that of glycosaminoglycan being next and that of collagen being slowest.

The change in textural characteristics of sea cucumber during the soaking process was evaluated by a penetration test machine. The penetration of dried sea cucumber was zero, which means

| Table 1 Chemical and textural changes of dried sea cucumber during soaking in distilled water |
|--------------------------------------|-----------------|-----------------|-----------------|-----------------|
| Rate of weight increase              | Water (%)       | Ash (%)         | Collagen (%)    | Glycosaminoglycan (%) | Penetration (mm) |
| Dried sea cucumber                   | 16.0 ± 0.3      | 70.4 ± 1.2      | 80.8 ± 1.9      | 90.3 ± 1.0        | 94.5 ± 0.1       |
| Soaked in water                      | 10.6 ± 0.6      | 2.2 ± 0.1       | 0.8 ± 0.1       | 0.4 ± 0.1         | 0.3 ± 0.0        |
| Before full-scale boiling            | 25.5 ± 2.6      | 10.6 ± 0.3      | 12.7 ± 5.2      | 5.8 ± 0.4         | 2.4 ± 0.3        |
| Full-scale boiled once               | 1.83 ± 0.03     | 0.67 ± 0.00     | 0.45 ± 0.03     | 0.25 ± 0.02       | 0.12 ± 0.02      |
| Full-scale boiled twice              | 0               | 2.1 ± 0.2       | 5.1 ± 0.2       | Unmeasurable      | Unmeasurable     |

All values are mean ± SD, n = 3.
that the dried sea cucumber was too hard for the pointer to penetrate (Table 1). The penetration was 2.1 mm after water soaking and 5.1 mm after preparatory boiling. The penetration gradually increased, because the sea cucumber gradually softened during the soaking process. The penetration after the first and second full-scale boilings could not be measured, because the pointer passed completely through the 40 mm body wall of the specimen. In the case of a dried sea cucumber soaked in distilled water, the water contents of the sea cucumber increased after the second boiling to the same level as that in raw sea cucumber, which made it soft enough to be edible. It is apparent that the body wall absorbed water and swelled during the soaking process and that the components of the body wall were eluted into the soaking solution.

**Effect of soaking conditions on the texture of dried sea cucumber**

The rate of weight increase and the component contents of sea cucumber that had been full-scale boiled in the four kinds of soaking solution after preparatory boiling are shown in Table 2. The rate of weight increase and component contents of sea cucumber varied according to the soaking solution. Potassium carbonate is the principal component of the solution used in Chinese cuisine for soaking hard foodstuffs, such as dried sea cucumber, and dried cuttlefish. The rate of weight increase and the moisture contents of sea cucumber soaked in a 0.2% potassium carbonate solution were the same as those soaked in water. The collagen and glycosaminoglycan contents were higher when soaked in water than in 0.2% potassium carbonate solution. It was clear that potassium carbonate accelerated the water absorption of dried sea cucumber, although the specimen contained more ash than the other specimens. It can be suggested that the potassium carbonate solution added to the boiling liquid was absorbed by sea cucumber. When the second full-scale boiling was performed with a 0.2% potassium carbonate solution, the sea cucumber swelled extraordinarily and disintegrated. Therefore, the full-scale boiling of sea cucumber in a 0.2% potassium carbonate solution was restricted to only once.

The rate of weight increase of the sea cucumber that had been soaked in coarse tea and boiled twice was 5.7, this being the least among the four specimens. The water content of this specimen was 88.3%, which was low. The contents of collagen and glycosaminoglycan were relatively large, the content of collagen being more than twice that in the other specimens. It can therefore be concluded that the components in the coarse tea controlled the water absorption by the sea cucumber. When the second full-scale boiling was performed with a 0.2% potassium carbonate solution, the sea cucumber swelled extraordinarily and disintegrated. Therefore, the full-scale boiling of sea cucumber in a 0.2% potassium carbonate solution was restricted to only once.

The rate of weight increase and the moisture contents of sea cucumber from full-scale boiling and rice-washing water were the same as those soaked in water. The contents of collagen and glycosaminoglycan were relatively large, the content of collagen being more than twice that in the other specimens. It can therefore be concluded that the components in the rice-washing water controlled the water absorption by the sea cucumber. When the second full-scale boiling was performed with water, the sea cucumber swelled extraordinarily and disintegrated. Therefore, the full-scale boiling of sea cucumber in water was restricted to only once.

**Table 2** Influence of the soaking solution on the rate of weight increase and composition (%)

<table>
<thead>
<tr>
<th>Soaking solution</th>
<th>Weight increase</th>
<th>Water</th>
<th>Collagen</th>
<th>Ash</th>
<th>Glycosaminoglycan</th>
</tr>
</thead>
<tbody>
<tr>
<td>After 24 h</td>
<td>Boiling water</td>
<td>5.8 ± 0.8abc</td>
<td>90.3 ± 1.0a</td>
<td>5.5 ± 0.3a</td>
<td>0.4 ± 0.1abc</td>
</tr>
<tr>
<td>of full-scale</td>
<td>Rice-washing water</td>
<td>5.8 ± 0.5abc</td>
<td>90.7 ± 1.6a</td>
<td>2.9 ± 0.6ad</td>
<td>0.4 ± 0.0a</td>
</tr>
<tr>
<td>boiling once</td>
<td>Coarse tea</td>
<td>5.4 ± 0.2a</td>
<td>86.7 ± 0.9b</td>
<td>7.5 ± 0.7c</td>
<td>0.8 ± 0.1b</td>
</tr>
<tr>
<td>0.2% K₂CO₃ (kansui)</td>
<td>6.2 ± 0.1b</td>
<td>91.3 ± 2.4ad</td>
<td>3.3 ± 0.5c</td>
<td>0.6 ± 0.1d</td>
<td>0.17 ± 0.02ad</td>
</tr>
<tr>
<td>After 24 h</td>
<td>Boiling water</td>
<td>7.6 ± 0.1c</td>
<td>94.0 ± 0.1c</td>
<td>2.3 ± 0.3d</td>
<td>0.2 ± 0.1d</td>
</tr>
<tr>
<td>of full-scale</td>
<td>Rice-washing water</td>
<td>6.8 ± 0.1d</td>
<td>92.8 ± 1.6d</td>
<td>2.4 ± 0.2d</td>
<td>0.3 ± 0.1de</td>
</tr>
<tr>
<td>boiling twice</td>
<td>Coarse tea</td>
<td>5.7 ± 0.2c</td>
<td>88.3 ± 1.2e</td>
<td>6.2 ± 0.6f</td>
<td>0.5 ± 0.1f</td>
</tr>
</tbody>
</table>

*ad Vertical values not sharing the same superscript letters are significantly different (P < 0.05).
All values are mean ± SD, n = 3.

**Table 3** Influence of soaking solution on the physical properties of dried sea cucumber

<table>
<thead>
<tr>
<th>Items of measurement</th>
<th>Water</th>
<th>Rice-washing water</th>
<th>Soaking solution</th>
<th>Coarse tea</th>
<th>0.2% K₂CO₃ (kansui)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness (kgf)</td>
<td>1.17 ± 0.12a</td>
<td>0.63 ± 0.05b</td>
<td>1.42 ± 0.12c</td>
<td>1.17 ± 0.10a</td>
<td></td>
</tr>
<tr>
<td>Cohesiveness (TU)</td>
<td>0.86 ± 0.01a</td>
<td>0.79 ± 0.03b</td>
<td>0.90 ± 0.01c</td>
<td>0.93 ± 0.02d</td>
<td></td>
</tr>
<tr>
<td>Breaking strength (g)</td>
<td>111.0 ± 13.8a</td>
<td>60.0 ± 4.2b</td>
<td>364.0 ± 47.8c</td>
<td>221.0 ± 34.7d</td>
<td></td>
</tr>
<tr>
<td>Breaking strain (%)</td>
<td>56 ± 1a</td>
<td>45 ± 1b</td>
<td>73 ± 3c</td>
<td>62 ± 1d</td>
<td></td>
</tr>
</tbody>
</table>

*ad Horizontal values not sharing the same superscript letters are significantly different (P < 0.05).
All values are mean ± SD, n = 5.
hardness and cohesiveness of sea cucumber soaked in the potassium carbonate solution were almost the same as those of the specimen soaked in distilled water. The values for the hardness, cohesiveness, breaking strength and breaking strain of the body wall of sea cucumber soaked in rice-washing water were smaller than those of the other three specimens. This indicates that when dried sea cucumber was soaked in the rice-washing water, it softened, lacked elasticity and easily disintegrated. However, the values for the hardness, breaking strength and breaking strain of sea cucumber soaked in coarse tea were higher than those of the other three specimens, suggesting that the specimen soaked in coarse tea had the hardest texture.

Figure 2 shows the results of the sensory evaluation. The appearance and texture varied widely according to the soaking solution used. Compared with the specimen soaked in distilled water, that soaked in rice-washing water was significantly more white, soft, lacking in elasticity and slimy, the spines on the body wall having fallen apart. The specimen soaked in coarse tea was black, the spines had retained their form well and the overall appearance was good. However, coarse tea intensified the astringency of sea cucumber, and its flavor was not liked by the evaluating panel. This specimen was also notably harder and less slimy than the control specimen. These results match those of the measured physical properties. Although the texture of the sea cucumber specimens varied according to the soaking solution, the preferences for the texture did not notably vary. The dried sea cucumber specimen soaked in potassium carbonate absorbed water rapidly, and its texture was comparatively good. It can therefore be concluded that the potassium carbonate solution was effective for shortening the soaking time needed for dried sea cucumber.

In the case of the sea cucumber specimen soaked in coarse tea, the rate of weight increase was smaller, the water content in the body wall was smaller, and the quantity of collagen contained in

![Fig. 2 Sensory evaluation scores of sea cucumber soaked in four kinds of solution. The sea cucumber soaked in distilled water was used as the reference. The panel was composed of 13 trained members. ○, Rice-washing water; △, coarse tea; ✡, 0.2% K₂CO₃ (kansui).]
the body wall was greater than those of the other specimens, which led to a greater breaking strength and harder texture. The characteristics of the sea cucumber specimen soaked in coarse tea suggest that coarse tea controlled the elution of collagen into the boiled solution. Such an effect of coarse tea on the change in texture has also been reported for fish bones: the backbone of Pacific saury heated in a catechin solution, the main ingredient of coarse tea, was harder than that boiled in water. It is surmised that catechin affected the collagen contained in the bone, resulting in hardening. Catechin accounts for not less than 75% of the polyphenols contained in coarse tea and tends to act on protein to form a complex. It is believed that the hardening of sea cucumber soaked in coarse tea was due to the same effect. It can be concluded that collagen, which is the principal component of the body wall of sea cucumber, was affected by catechin and made water insoluble, this controlling the water absorption and swelling of the specimen and hardening the body wall. In contrast, the chemical composition of the specimen soaked in rice-washing water was almost the same as that of the specimen soaked in distilled water. The reason why the sea cucumber soaked in rice-washing water was softer and less elastic than that soaked in distilled water is not explained by the chemical composition of the body wall. However, the sensory evaluation indicates that the spines of the sea cucumber soaked in rice-washing water fell apart, suggesting that the components of the body wall had been substantially eluted into the soaking solution.

### Difference in the distribution of collagen between the soaking solutions

The component contents and quantity of water-soluble collagen in the outer one-third of the body wall were examined (Table 4). The contents of water and collagen in the outer one-third of the body wall of the specimens soaked in distilled water and coarse tea were almost the same as those in the whole body wall. Contrary to this, the content of collagen contained in the outer one-third of the body wall was 1.3% after soaking in rice-washing water, this being almost half that in the whole body wall. The quantity of water-soluble collagen in this case was relatively high at 0.46%, accounting for 35% of the whole collagen. This proves that soaking in rice-washing water resulted in the collagen at the surface of the body wall being eluted into the boiling solution. It is surmised that this depletion of collagen from the surface of the body wall resulted in the texture becoming softer and less elastic after soaking in the rice-washing water. Although rice-washing water and rice bran are used for removing the distasteful substances contained in herring, Japanese radish and bamboo shoot, the effects of rice-washing water and rice bran on the texture of foodstuffs have rarely been reported. Only the acceleration of the solubilizing effect of rice bran on *Ceramium boydenii*, and the possible solubilizing effect of phytic acid contained in the water-soluble substances in an extract from rice bran on *Ceramium boydenii* have been reported. It can be surmised that the protein-breakdown enzymes contained in rice are related to the solubilization of the collagen in cucumber. However, the cause of this solubilization remains to be studied.

### References


### Table 4 Comparison of the collagen contents in the outer third wall surface of sea cucumber between the soaking solution (%)

<table>
<thead>
<tr>
<th>Soaking solution</th>
<th>Water</th>
<th>Collagen</th>
<th>Water-soluble collagen</th>
<th>Glycosaminoglycan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deionized distilled water</td>
<td>94.1 ± 0.6</td>
<td>2.3 ± 0.0</td>
<td>0.36</td>
<td>0.05 ± 0.00</td>
</tr>
<tr>
<td>Rice-washing water</td>
<td>93.8 ± 0.3</td>
<td>1.3 ± 0.2</td>
<td>0.46</td>
<td>0.06 ± 0.01</td>
</tr>
</tbody>
</table>

All values are mean ± SD, n = 3.