Note

Anti-Obesity Effect on Rodents of the Traditional Japanese Food, Tororokombu, Shaved Laminaria

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Tororokombu is a traditional Japanese food made from edible kelp. The way to make tororokombu is characterized by shaving kelp very thinly. It was found that tororokombu decreased the serum triglyceride level induced by oil administration to rats and had an anti-obesity effect on obese mice induced by a high-fat diet. These effects were more powerful than those of non-shaved kelp.

Key words: edible kelp; anti-obesity; alginate; high-fat diet; triglyceride

Obesity is an abnormal condition of accumulating excessive triglyceride in adipose tissue. Obesity is the most important risk factor of the metabolic syndrome such as hypertension, type 2 diabetes and hyperlipemia.1,2 Furthermore, the metabolic syndrome develops atherosclerotic diseases, whose fatality is very high, when the symptom gets worse.3,4 It is therefore important to prevent or abate obesity.

Tororokombu (TK) is a traditional Japanese food which was developed in the 1620s. The main materials are edible kelp, Laminaria sp. named Kombu in Japanese. TK is made by a series of processes, involving pickling in vinegar, cutting, compressing, molding and shaving. There are two characteristics shown in these processes: one is the absence of decoction in hot water and a seasoning liquid and the other is shaving very thinly, unlike other processed foods from kelp. It was therefore expected that most of components would be retained in kelp during processing and be easily eluted during digestion. The extracts and components have already been demonstrated to exhibit many bioactivities.5–7 However, the anti-obesity effect in vivo has not previously been reported. Accordingly, we examined in the study the anti-obesity action of kelp and the influence of the shaving process for TK on anti-obesity in this study.

TK and non-shaved kelp (NSK) were obtained from Fujicco Co., Ltd. (Kobe, Japan). The materials consisted of two kinds of edible kelp, Laminaria japonica (80%) and Laminaria ochotensis (20%). The non-shaved kelp was made according to the processing method for Tororokombu, except for the shaving process. Each sample was broken into similarly sized pieces (425 μm–600 μm).

The effect of NSK and TK on the absorption of triglycerides in the intestine was first investigated by an oil-loading test with female SD rats (7 weeks old). Animal studies were done according to the 2006 guidelines entitled Notification no. 88 of Ministry of the Environment in Japan and Guidelines for Animal Experimentation of Tokyo University of Marine Science and Technology with the approval of Animal Care and Use Committee of Tokyo University of Marine Science and Technology. After fasting for 24 h, the SD rats were assigned to three groups. Distilled water (DW) or the sample solution (20 ml/kg) was orally administered to each group before an oral administration of corn oil (5 ml/kg). The area under curve (AUC) value was calculated from the time-course plot of serum TG as the index of the total absorbed amount. The elevation of serum TG level in the NSK- and TK-treated groups was significantly lower than that of the control group (Fig. 1A). In the case of the evaluation by AUC value, the value for the TK-treated group was significantly lower than that of the control group (Fig. 1B). On the other hand, there was no difference in AUC value between the control and NSK-treated group. Therefore, it was found that NSK and TK had an inhibitory effect on fat absorption.

Secondly, the anti-obesity effect of NSK and TK was investigated by a long-term experiment on obese mice induced by a high-fat diet (HFD) for 63 d. Female ddY mice (4 weeks old) were preliminarily bred with a normal diet (ND) for 1 week and then assigned to four groups: ND group, HFD group, HFD + NSK group and HFD + TK group. ND contained 4% beef tallow, 14% casein, 62.5% cornstarch, 10% sucrose, 5% cellulose, 3.5% mineral mixture, and 1% vitamin mixture. The high-fat diet contained 40% beef tallow, 14% casein, 26.5% cornstarch, 10% sucrose, 5% cellulose, 3.5% mineral mixture, and 1% vitamin mixture. The HFD + NSK and HFD + TK groups were fed on HFD contain-

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Abbreviations: TK, tororokombu; NSK, non-shaved kelp; TG, triglyceride; AUC, area under curve; TC, total cholesterol; ND, normal diet; HFD, high-fat diet; DW, distilled water

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ing 3% NSK and TK, respectively. On the 65th, 66th and 67th days after breeding started, the feces of each group were collected. There was hardly any difference in the total food intake for 63 d among the HFD, HFD + NSK and HFD + TK groups (HFD, 1348.6 g; HFD + NSK, 1326.4 g; HFD + TK, 1407.1 g). As shown in Table 1, the parauterus adipose tissue weight and hepatic TG level in the HFD + TK group were significantly lower than those in the HFD group. The body weights on the 63rd days after breeding started and the serum TC level in both the HFD + NSK and HFD + TK groups were significantly lower than those in the HFD group. The parauterus adipose tissue weight, and hepatic TG, serum TG and TC levels in the HFD + TK group were significantly less than those in the HFD + NSK group. Consequently, it was demonstrated that TK ingestion depressed the visceral fat accumulation caused by HFD and that this effect of TK was more powerful than that of NSK. Moreover, the fecal TG and TC levels in the HFD + TK group were significantly higher than those in the HFD group, and fecal TG in the HFD + TK group was significantly higher than that in the HFD + NSK group. It is thought from these results that TK showed anti-obesity and hypolipidemic effects because of the TG and cholesterol excretion in the feces.

Lastly, the amount of components eluted from NSK and TK into a weakly alkaline buffer was measured (n = 3). NSK and TK were each mixed with pre-incubated phosphate-buffered saline (pH 8.0) and incubated for 30 min (37 °C, 135 rpm shaking speed). Each solution was then centrifuged at 3,500 rpm for 30 min to obtain the supernatant. The residue was washed twice with DW and centrifuged at 3,500 rpm for 30 min. The washed supernatants were mixed and lyophilized to measure the component weights. The uronic acid content was analyzed for an alginate determination by the carbazole method. The amount of total eluted components (810 ± 2 mg/g) and alginate (219 ± 4 mg/g) from TK was significantly larger than that from NSK (732 ± 2 mg/g and 170 ± 2 mg/g, respectively) into the weakly alkaline buffer. TK was thought to be because TK was very thin by the Shaving process and that most of the kelp cells had been crushed, and that the increase in eluted components in the intestines enhanced the anti-obesity effect. The weakly alkaline fraction of TK including a lot of alginate had an inhibitory effect on triglyceride absorption, whereas the DW-soluble fraction containing only a little of them did not have such an effect (data not shown). In the previous reports, it has been shown that alginate had hypoglycemic and cholesterol-lowering actions, and that viscous soluble dietary fiber decreased the emulsification and lipolysis rate of triglycerides.8–12 Thus, alginate is thought to be one of the active ingredients included in TK. Moreover, edible kelp contains fucoidan and fucoid, and it has been reported that these ingredients suppressed the adipocyte differentiation, upregulated UCP1 expression in white

![Fig. 1. Effects of NSK and TK on TG Absorption after an Oral Administration of Corn Oil to Rats.](image)

To the control group (unfilled circles), NSK-treated group (filled circles) and TK-treated group (unfilled triangles) were respectively administered DW (20 mL/kg), NSK (1,000 mg/kg) and TK (1,000 mg/kg) before an oral administration of corn oil (5 mL/kg). Data (n = 6) are presented as the mean ± S.E. and were analyzed by one-way ANOVA and subsequent Dunnet test. *p < 0.05, **p < 0.01, ***p < 0.005 vs. the control group.

**Table 1.** Body, Parauterus Adipose Tissue and Liver Weights, and TG and TC in the Liver, Serum and Feces of Mice Fed with a HFD (n = 7, 8)

<table>
<thead>
<tr>
<th></th>
<th>ND group</th>
<th>HFD group</th>
<th>HFD + NSK group</th>
<th>HFD + TK group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight (g)</td>
<td>31.8 ± 1.0***</td>
<td>40.6 ± 2.1</td>
<td>37.3 ± 1.2*</td>
<td>34.0 ± 1.0**</td>
</tr>
<tr>
<td>Parauterus adipose tissue (mg/g of body weight)</td>
<td>30.6 ± 5.3**</td>
<td>62.4 ± 7.2</td>
<td>55.0 ± 7.0</td>
<td>31.1 ± 5.0***</td>
</tr>
<tr>
<td>Liver (mg/g of body weight)</td>
<td>38.2 ± 0.8</td>
<td>39.2 ± 1.2</td>
<td>37.1 ± 3.0</td>
<td>34.7 ± 1.0</td>
</tr>
<tr>
<td>Hepatic TG (mg/g of liver)</td>
<td>96.4 ± 5.3**</td>
<td>138 ± 8</td>
<td>132 ± 19</td>
<td>95.3 ± 12.6**</td>
</tr>
<tr>
<td>Hepatic TC (mg/g of liver)</td>
<td>8.31 ± 1.10</td>
<td>8.04 ± 1.19</td>
<td>8.04 ± 0.98</td>
<td>8.07 ± 1.48</td>
</tr>
<tr>
<td>Serum TG (mg/dl)</td>
<td>157 ± 18</td>
<td>150 ± 18</td>
<td>171 ± 20</td>
<td>126 ± 7**</td>
</tr>
<tr>
<td>Serum TC (mg/dl)</td>
<td>116 ± 9**</td>
<td>185 ± 10</td>
<td>152 ± 11*</td>
<td>114 ± 10**</td>
</tr>
<tr>
<td>Fecal weight (mg/d)</td>
<td>198 ± 9*</td>
<td>247 ± 5</td>
<td>281 ± 19</td>
<td>314 ± 18*</td>
</tr>
<tr>
<td>Fecal TG (mg/d)</td>
<td>0.339 ± 0.106</td>
<td>2.02 ± 0.31</td>
<td>4.78 ± 0.14**</td>
<td>7.96 ± 0.88***</td>
</tr>
<tr>
<td>Fecal TC (mg/d)</td>
<td>4.80 ± 0.65*</td>
<td>7.76 ± 1.07</td>
<td>9.93 ± 1.18</td>
<td>13.4 ± 0.5**</td>
</tr>
</tbody>
</table>

Data are presented as the mean ± S.E. and were analyzed by one-way ANOVA and subsequent Dunnet test.

ND, normal diet; HFD, high-fat diet; NSK, non-shaved kelp; TK, tororokombu
*p < 0.05, **p < 0.01, ***p < 0.005 vs. HFD group. *p < 0.05, **p < 0.01, ***p < 0.005 HFD + TK group vs. HFD + NSK group.
adipose tissue and inhibited the activity of the pancreatic lipase. Therefore, it is thought that these ingredients also contributed to the anti-obesity effect of TK.

In conclusion, edible kelp presented an inhibitory effect on fat absorption, and the action was enhanced by the increase in components eluted from it by the shaving process. In addition, it was confirmed that tororokombu, and not non-shaved kelp, had an anti-obesity effect. Therefore, tororokombu will be effective for preventing and abating the metabolic syndrome, and particularly obesity.

References