Note

Sensory Analysis of the Taste of Ayu Sampled from Different River Environments

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It is widely believed that attached diatoms are the best food source for freshwater ayu Plecoglossus altivelis (Temminck et Schlegel) in Japan. However, sensory testing by a panel consisting of 40 untrained tasters and analyses of gut content showed that there was no significant correlation between preference scores for fish taste and the dominance of diatoms in the algal assemblages fed upon by ayu in the Yahagi River, Aichi Prefecture, Central Japan. Ayu that fed on the filamentous blue-green algae Homeothrix varians was evaluated higher for aroma and fat content than those that fed on diatoms. Ayu feeding on diatoms were collected in the lower reaches of the Yahagi River which receive domestic sewage. In the absence of more detailed analyses, exposure to sewage is considered to confer a characteristic aroma on Ayu.

Keywords: attached algae, Ayu, gut content, sensory testing, Yahagi River

Introduction

Ayu, Plecoglossus altivelis (Temminck et Schlegel), a member of Plecoglossidae, is one of the most popular freshwater fishes in Japan. Consumers are particularly fond of its cucumber- or watermelon-like scent. The fish is typically grilled with only salt, and is typically eaten whole, including the gut (Hitomi, 1697). It is believed that the aroma, taste, and size of herbivorous ayu are determined by the food in the gut, which typically consists of various species of periphytic algae. Fishermen claim that, compared to green (Chlorophyceae) or blue-green algae (Cyanophyceae), diatoms (Diatomaceae) are the best food for ayu. Fishermen object to water pollution and channel modification, because these have a negative effect on the biomass and species composition of the periphytic algal communities, and subsequently, on the aroma, taste, and size of ayu.

Nevertheless, the direct relationship between fish aroma and the food source of ayu has not yet been clarified. The aromatic components of the body surface of ayu are not considered to be derived from algae (Hirano et al., 1992), as the carnivorous trout Coregonus clupeaformis has a similar aroma as ayu (Josephson et al., 1983).

The belief that ayu size is strictly determined by diet is also doubtful. For example, Hodoki et al. (2003) showed that there was no significant difference in body length and weight between two ayu populations that fed on either diatoms or blue-green algae.

The relationship between market value of ayu and its food source also remain unresolved. It is possible that the river environment has a marked impact on the taste of the ayu as it is the river that directly affects the periphytic algae and the ayu that live there. In this study, we present the results of sensory evaluations of the aroma and taste of Ayu, and discuss the taster-preference in relation to algal species composition in the fish gut and the river environment.

Materials and Methods

Description of study area We selected the Yahagi River in central Japan as the study site because the ayu and the river environment of the area have been extensively investigated by the Toyota Yahagi River Institute since 1994 (Niimi, 1997).

The Yahagi River rises in Mt. Ookawairi-Yama (1,908 m) and discharges into Mikawa Bay. The main stream is 118 km-long and drains a catchment area of 1,830 km². Seven dams exist along the main river and approximately 1,100,000 people in the catchment (Fig. 1). Organic matter originating from domestic waste and plankton in water released from the dams upstream are the main pollution loads.
used for the sensory tests were standardized by selecting only those individuals with body length of 19.9 ± 1.4 cm in. Within 3 h after capture, the captured fish were transferred from river water and individually sealed in plastic bags to avoid contamination of the aroma. Fish were then preserved at −20°C.

Sensory testing Samples were kept frozen for approximately two weeks, when sensory tests were performed on 16 September 2006. The 40 untrained panel members consisted of 30 men and 10 women, ranging in age from twenties to seventies (mode: 55). The fish samples were sprinkled with salt and roasted by a chef over charcoal fire, before being cooled to room temperature before testing. One fish from each of the five sampling points was served to each member.

We did not determine the sex of the fish that were served, neither did we prescribe which part of the fish should be tasted. After tasting one sample from each of the five sample sites, panel members were asked to score the samples by aroma, taste, and fat content, with a score of 1 indicating the top score and a score of 5 indicating the lowest. If they are unable to score the taste, then they were allowed to leave the answer blank. Scores were subjective, which meant that one panel member may favor cucumber-like smell of ayu while another may dislike it. Evaluation of fat content was also subjective. Although concentrations of lipids and fatty acids in ayu have been shown to fluctuate seasonally (Hirano and Suyama, 1983), this variation in fat content has not been examined within the context of the effect on taste. In order to avoid carryover samples, panel members were required to rinse their mouths with mineral water after testing each sample. After three sensory evaluations, we asked them to score their general preferences, not as the sum of each sensory score, but as an evaluation of the whole sample.

Statistical significance was determined by the Newell & MacFarlane and Krammer methods. If the total scores were not significant according to the Krammer table, then the taste was considered preferable. If the Krammer table scores were high, then the taste was considered unfavorable. Differences in preference were elucidated by the Newell & MacFarlane method. Valid answers for the general preference, aroma, taste and fat content were obtained from 39, 18, 19 and 16 of the respondents, respectively.

Reference of water quality information Water qualities for the Yahagi River reported by Shiragane (2002) were used in our study to evaluate the river condition.

Examination of gut contents Five ayu collected at each station were subjected to gut content analysis. Gut contents of the front digestive tract were emptied on a slide glass. Since dominant algal species is the filamentous blue-green algae (Homeothrix varians) and it is difficult to count cell
number, we indicated its relative abundance as a proportion of the microscopic field occupied by the alga. This was done by diving the microscopic field into a grid of 200 squares (10 × 20). The taxonomic category of the algae in each square was then noted. A total of 4,000 grids were examined at each sampling station. Nomenclature followed Kramer & Lange-Bertalot (1991) for the Bacillariophyceae and Hirose and Yamagishi (1977) for the other taxa.

Results

The order of preference Average scores for aroma, taste, fat content, and general preference are shown in Table 1. The mean and standard deviations of general preference scores of the fish from stations 1 − 5 were 3.6 ± 1.2, 3.1 ± 1.4, 2.6 ± 1.5, 2.3 ± 1.3 and 3.4 ± 1.3, respectively. A significant difference was detected between Stas. Y1 and Y4 by Krammer’s method, indicating that the ayu from Sta. Y4 were significantly more preferred over those of the other stations (p < 0.05). Similarly, the fish from Sta. Y1 were evaluated significantly lower than the fish from the other stations (p < 0.05). Compared to fish from the other stations, the aroma and fat content of fish from Sta. Y4 were also preferred (p < 0.05), although the response rate for aroma and fat content was not high; 14 out of 18 responses for aroma evaluated Y4 higher than Y1, and 14 out of 16 responses for fat content evaluated Y4 higher than Y1. No significant differences between stations were observed for taste.

Newell & MacFarlance’s method detected significant differences for aroma and general preference between Stas. Y1 and Y4, and between Stas. Y4 and Y5.

The statistical analyses showed that fish from Sta. Y4 were more preferred than fish from the other stations, especially Stas. Y1 and Y5. The tests also showed that general preference was largely dependent on aroma.

Digestive tract content Algal species compositions in the guts of ayu are shown in Table 2. Dominant algal species were *Homeothrix varians* (Cyanophyceae) and some species of diatoms (Bacillariophyceae) such as *Melosira varians* and *Fragilaria* spp. The relative abundance of the algae in the gut (i.e. Cyanophyceae/ Bacillariophyceae) at Stas. 1 − 5 were 0.48, 2.81, 3.98, 6.81 and 3.91, respectively. Filamentous green algae, such as *Cladophora* sp., were relatively rare and digestion of these cells was not observed.

Water quality in the Lower Yahagi River In contrast to the stations upstream, the water quality at the lowest station, Y1, was reported by Shiragane (2002) as being polluted by domestic sewage. Though indices of organic pollution such as Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD) were approximately 2 and 1 mg/L, respectively, the mean annual concentration of NH₄-N was 0.03 mg/L, with levels greater than 0.08 mg/L recorded in winter. Conversely, NH₄-N concentrations near Sta. Y4 were less than 0.01 mg/L. The effects of the two dams between Stas. Y1 and Y4 are not described in the report.

Table 1. Sensory analyses of ayu captured at different points along the Yahagi River.

<table>
<thead>
<tr>
<th>General preference</th>
<th>Aroma</th>
<th>Fat</th>
<th>Taste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sta.  Y 1</td>
<td>3.6 ± 1.2*</td>
<td>3.7 ± 1.0*</td>
<td>3.6 ± 1.2*</td>
</tr>
<tr>
<td>Y 2</td>
<td>3.1 ± 1.4</td>
<td>3.1 ± 1.2</td>
<td>2.9 ± 1.5</td>
</tr>
<tr>
<td>Y 3</td>
<td>2.6 ± 1.5</td>
<td>2.6 ± 1.2</td>
<td>3.1 ± 1.4</td>
</tr>
<tr>
<td>Y 4</td>
<td>2.3 ± 1.3*</td>
<td>2.0 ± 1.4*</td>
<td>2.1 ± 1.3*</td>
</tr>
<tr>
<td>Y 5</td>
<td>3.4 ± 1.3</td>
<td>3.7 ± 1.4</td>
<td>3.3 ± 1.1</td>
</tr>
</tbody>
</table>

See Figure 1 for the location of sampling stations Y1 to Y5. Results are shown as mean scores with standard deviations. * indicate significant differences (p < 0.05) detected by the Krammer’s method.

Table 2. Algal species composition in the guts of fish caught at five sample stations.

<table>
<thead>
<tr>
<th>Bacillariophyceae (B)</th>
<th>Cyanophyceae (C)</th>
<th>C/B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sta.  Y 1</td>
<td>4.1 ± 1.7</td>
<td>2.0 ± 1.0</td>
</tr>
<tr>
<td>Y 2</td>
<td>3.6 ± 1.1</td>
<td>10.1 ± 6.7</td>
</tr>
<tr>
<td>Y 3</td>
<td>5.5 ± 2.1</td>
<td>21.9 ± 15.5</td>
</tr>
<tr>
<td>Y 4</td>
<td>4.3 ± 4.9</td>
<td>29.3 ± 11.2</td>
</tr>
<tr>
<td>Y 5</td>
<td>5.4 ± 4.6</td>
<td>21.1 ± 16.6</td>
</tr>
</tbody>
</table>

See Figure 1 for the location of sampling stations Y1 to Y5. Results are mean scores for the proportion (%) of squares occupied by algae in an ocular grid relative to the number of squares that did not contain any algae (± standard deviation; n = 4,000 grid samples). * indicate significant differences (p < 0.05) in relative proportions of Bacillariophyceae and Cyanophyceae.
Discussion

The sensory testing revealed that the most preferred ayu fed on blue-green algae (Sta. Y4), and the least preferred fish fed on diatoms (Sta. Y1). Although significant differences were also detected in aroma and fat content, these evaluations require further analysis as the response rates for taste, aroma, and fat content were lower than they were for the general evaluation. In addition, we were unable to account for possible differences in taste between male and female fish, at least for fat content (Joeng et al., 2000). These findings do not support the widely held belief that a diet of diatoms improves the taste of ayu flesh. Although ayu fed on blue-green algae such as Anabaena spp. have been reported to have a grassy smell (Oohashi and Hatama, 2005), *Homeothrix varians* is considered to be a good food source for ayu in the Yahagi River (Uchida, 2002) and other Japanese rivers (Abe et al., 2003, 2005). Nakagawa et al. (2002) showed that in contrast to green algae, blue-green algae and diatoms are well digested by ayu.

*Homeothrix varians* has been reported in river reaches downstream from dams in southwestern Japan (Morishita and Morishita, 2000). However, Abe et al. (2000) claimed that the dominance of *H. varians* was due to high grazing pressure by ayu, because filamentous blue-green algae grows faster than diatoms. Although we did not examine the reasons underlying the dominance of *H. varians* in the Yahagi River, differences in the quality of the ayu food source does not appear to explain the differences observed in sensory tests.

Another reason for the low evaluation scores of the fish from Sta. Y1 may be due to the effect of domestic sewage on water quality. Ose et al. (1975) proposed that volatile fatty acids originating from domestic sewage confer an unfavorable odor to fishes. It is of interest that the scores of aroma agreed with the scores of general preference. From this point of view, the low score for the uppermost station (Y5) seems odd and we suspect that the quality of water released from dams is responsible; the largest dam on the river, the Yahagi Dam, is located in the upstream reaches of the river. The impounded water of is channeled and released immediately upstream of Y5. Loads of organic matter due to planktonic production in reservoirs and lakes is most pronounced immediately downstream from such impoundments, becoming less severe as the water flows downstream (Murakami et al., 1994). Thus, compared to organic loads downstream, the loads at Y5 are considered to be high. In addition, some planktonic blue-green algae behave as odorants (Oohashi and Hatama, 2005). The problematic odors in fishes are serious in some Japanese rivers, although causal factors and contributing processes are not clear (Yasuhashi, 1995). Further investigations are therefore required to resolve this issue.

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References


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