Aquaculture of Japanese flounder (*Paralichthys olivaceus*), also known as Korean flounder, olive flounder or bastard halibut (Figure 1) started in the mid-1970s and commercial production became extensive in the early 1980s with development of fingerling production and rearing techniques in Japan. Production has increased gradually during the past two decades and was 7,589 tons in 1998, nearly equal to that of the wild catch. It ranked fourth among marine cultured finfish in Japan after yellowtail (*Seriola quinqueradiata*), red sea bream (*Pagrus major*), and coho salmon (*Oncorhynchus kisutch*). Flounder is highly valued and its market price (20 to 25 US$/kg live in Tokyo) is 2 to 3 times higher than that of yellowtail and red sea bream. Generally, farmers obtain 1 to 2 g fingerlings from commercial hatcheries in winter to early spring and rear the fish to sizes ranging from 800 g to more than 1 kg over 12 to 24 months. Wild fingerlings are rarely used. Unlike other marine finfish species that have been produced in floating net cages, land-based (onshore) culture tanks are the prevalent culture system for Japanese flounder. Locally available feed fish such as sand lance or sardines has been used for growout of Japanese flounder. However, the use of dry and moist pellets has increased recently.

The protein content of commercial fish diets is much higher than for domesticated animals, ranging from 30 percent to more than 50 percent protein on a dry weight basis. Most fish have only a limited ability to utilize dietary carbohydrate as an energy source, thus a higher percentage of protein in the diet is required. However, it has been determined that some fish species, mostly freshwater...
fish, can utilize dietary carbohydrate and lipid to some extent (National Research Council 1993). This makes it possible to reduce dietary protein content, commonly referred to as the protein sparing effect, and also increase protein utilization.

The protein sparing effect in the diet for flounder has not been fully clarified as yet. Based on research to date, this fish species is highly carnivorous and does not utilize much dietary carbohydrate and lipid as energy sources. Increasing dietary carbohydrate (dextrin or potato starch) did not improve growth and protein utilization, and excess amounts of carbohydrate may have an adverse effect on the growth of this fish (Kikuchi et al. 1998, Lee et al. 2000). Addition of pollack liver oil does not have a positive effect on the growth of flounder, independent of dietary protein level and fish size (Sato 199, Kikuchi et al. 2000). Excess amounts of lipid in the diet slightly improved the protein efficiency ratio, however, it also caused high fat deposition in the dorsal and “Engawa” (along the anal and dorsal fin) muscles; undesirable quality changes. Therefore, the diet for growout of Japanese flounder should have a high protein to energy ratio, requiring high percentages of quality protein ingredients.

### Protein Source

Japanese commercial feed formulations for marine fish have depended on sardines as the primary protein source. This was due to stable supply and low market price, high nutritive value and palatability. However, the catch of sardines has decreased drastically from 4.7 million tons in 1988 to 0.7 million tons in 1998. The reduced supply of sardine meal as well as other fish meals has resulted in increased feed costs. Therefore, finding alternatives to fish meal is a high priority, regardless of the effects of aquaculture on world fish supplies. There are several feed ingredients used as primary protein sources. Included are soybean meal, corn gluten, rapeseed meal, canola meal, meat and bone meal, feather meal and blood meal (National Research Council 1993). Some of them have moderate or high protein content with a good amino acid composition and are highly available at reasonable market prices. Using these ingredients as dietary protein sources to replace fish meal would reduce feed costs that comprise more than half of the total production cost in finfish aquaculture.

The availability of alternative protein sources to fish meal in feed for Japanese flounder has been examined. Experimental diets were formulated with fish meal protein in the control diet and test diets where fish meal was either partially or totally replaced with non-fish meal ingredients. The diets were fed to fish for several weeks. Potential replacement level for each ingredient was evaluated based on fish weight gain, feed efficiency or protein efficiency ratio and chemical composition of fish body and/or blood. Digestibility coefficients are also a useful indicator of performance.

We chose blue mussel meat, and defatted soybean (SBM), corn gluten (CGM), silkworm pupae, feather meal, meat and bone meal, meat meal, and cuttlefish meal

<table>
<thead>
<tr>
<th>Protein source</th>
<th>Replacement of dietary fish meal (% protein)</th>
<th>Crude protein of test diets (%)</th>
<th>Amino acids supplements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defatted soybean meal</td>
<td>50</td>
<td>49-51</td>
<td>Necessary</td>
</tr>
<tr>
<td>Corn gluten meal</td>
<td>40</td>
<td>54-57</td>
<td>Necessary</td>
</tr>
<tr>
<td>Silkworm pupa meal</td>
<td>20</td>
<td>45-48</td>
<td>Not necessary</td>
</tr>
<tr>
<td>Feather meal</td>
<td>40</td>
<td>53-56</td>
<td>Necessary</td>
</tr>
<tr>
<td>Meat meal</td>
<td>60</td>
<td>52-56</td>
<td>Not clear</td>
</tr>
<tr>
<td>Meat and bone meal</td>
<td>20</td>
<td>48-50</td>
<td>Not clear</td>
</tr>
<tr>
<td>Blue mussel meal</td>
<td>&gt;60</td>
<td>44-48</td>
<td>Not necessary</td>
</tr>
<tr>
<td>Cuttlefish meal</td>
<td>100</td>
<td>51</td>
<td>Not necessary</td>
</tr>
</tbody>
</table>
as alternative ingredients to fish meal. Feeding experiments were conducted with juvenile Japanese flounder of less than 10 g initial body weight. Results are summarized in Table 1. As is generally known, cuttlefish meal is an excellent ingredient, having the required amino acids in the proper balance, and cuttlefish can replace all of the fish meal in the diet for flounder. The only problem with using cuttlefish meal for growout diet is the price, which is too high. Other ingredients except blue mussel meat are considered to be practical, and 20 to 40 percent fish meal protein can be replaced by feather meal, 20 percent by meat and bone meal and silkworm pupae meal, 60 percent by meat meal, and 40 percent by CGM. Soybean meal, one of the most promising ingredients in fish feeds, and widely evaluated with respect to various fish species, can replace about 50 percent of fish meal protein in the diet of flounder. However, it should be noted that most of these levels are achieved when certain essential amino acids were added in crystalline form to bring the levels to the required amounts. Otherwise (Figure 1), the fish growth was reduced significantly (Kikuchi 1999a, Alam et al. 2000). Ten amino acids: arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine are considered to be essential for Japanese flounder.

Blue mussel meat is considered to be an attractive ingredient, although using mussel meat as the main ingredient of fish diets is not practical due to the low supply and high price. Mussel meat successfully replaced more than 60 percent of fish meal protein in the diet for flounder without supplemental amino acids (Table 1). In addition, inclusion of blue mussels in the diet promotes the growth of flounder by stimulating feeding, thereby increasing feed intake. (Kikuchi 1998). Because significant positive effects on growth were obtained even when the dietary inclusion level was only 5 percent on a dry matter basis, mussel meat can be used as an additive in flounder diets.

**Combined Use of Alternative Ingredients**

Each dietary ingredient has its own amino acid profile and combined use of several ingredients may improve dietary amino acid composition. For instance, SBM and CGM are promising alternative ingredients to fish meal in the diet for Japanese flounder as mentioned above. However, SBM is insufficient in lysine and methionine while CGM is insufficient in lysine. On the other hand, blood meal (BM) is rich in lysine and has a moderate methionine content. Addition of BM to the fish meal and SBM diet improved the nutritive value of the diet as shown by better growth (Figure 2) that was comparable to the control group when 45 percent of fish meal protein in the control diet was substituted (Kikuchi 1999b). However, adjustment of the amino acid balance in the diet does not always produce good results. For example, addition of BM negatively affected the growth of fish when CGM was used as the major alternative for fish meal despite improvement of the amino acid profile of the diet (Figure 3). In addition, the growth of fish fed fish meal, SBM and CGM diet was inferior to that of fish meal SBM and BM diet, as shown in Figure 2. Inclusion of 5 percent blue mussel meat (BMM) to the diets made their nutritive value equal, and growth surpassed that of the growth of fish on the control diet. In this case, the amino acid profile of the diet was not improved by the inclusion of BMM. On the other hand, such a positive effect of
BMM inclusion was not obtained with the fish meal, CGM and BM diet (Figure 3). While improving the essential amino acid profile of the diet is a primary consideration in the development of commercial diets using non-fish meal ingredients as the major protein source, it is not the only criterion, and a combination of ingredients should be considered.

Conclusions

It is possible to reduce the fish meal in Japanese flounder diets by about half by using plant ingredients and/or poultry byproducts. However, potential inclusion level of these ingredients has been evaluated based on the growth of fish, feed efficiency, and chemical analyses of the cultured fish in a feeding trial of a few weeks and with fish of less than 10 g initial body weight. Little information has been obtained on the quality of cultured fish fed these types of alternative diets. Japanese flounder is a highly valued fish and is mostly eaten as raw fish Sashimi or Sushi in Japan and it is necessary to examine the effect of dietary composition on the taste or flavor of fresh fish. Therefore, long term feeding experiments up to commercial size (800 to 1000 g) and sensory analyses of the cultured fish are needed to clarify such issues related to the use of alternative ingredients.

References


Notes

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