Macro nutrient requirement of Japanese flounder *Paralichthys olivaceus*

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Abstract

Japanese flounder *Paralichthys olivaceus* is one of the most popular marine cultured finfish in Japan, and has a good market price of 2000 JPY/kg that is 2 to 3 times higher than those for yellowtail and red sea bream. Aquaculture production of Japanese flounder reached a peak of 8583 MT in 1997 and decreased linearly to 4592 in 2005 due to increasing imports of flounders. Unlike other marine finfish species that have been produced with floating net cages, land-based culture tanks with running seawater (flow-through) are the prevalent culture system for flounder aquaculture accounting for 75% of production area in 2005. Several manufacturers produce commercial dry pellets for grow-out, however, considerable amount of raw fish has still been supplied as whole or moist pellets. This paper describes the present status of commercial production of Japanese flounder in Japan, and also provides up-to-date information on the nutritional availability of dietary protein, lipids, and carbohydrates for grow-out of Japanese flounder.

Introduction

Seedling production has been conducted with various flatfish species for stock enhancement in the coastal zone of Japan. However, Japanese flounder "Hirame" *Paralichthys olivaceus* (left-eye flounder) is the only flatfish species that has been commercially produced. Aquaculture of Japanese flounder started in the middle 1970's in Japan and commercial production became extensive in the 1980's with development of fingerling production and farming techniques. Production increased rapidly from 648 MT in 1983 to 6000 MT in 1990, and reached a peak of 8583 MT in 1997, more than the fishery catch in Japan (Fig. 1). However, production decreased gradually to 4592 MT in 2005 due to declining market price caused by increases in flounder imports and the poor economic conditions. Most of the imported fish is from Korea where the production is about 10 times higher than Japan. Aquaculture production of Japanese flounder ranked fourth among marine cultured finfish, and is much lower than for yellowtail *Seriola quinqueradiata* and red sea bream *Pagrus major*, the most popular marine cultured finfish in Japan with production of 159761 and 76128 MT, respectively, in 2005.

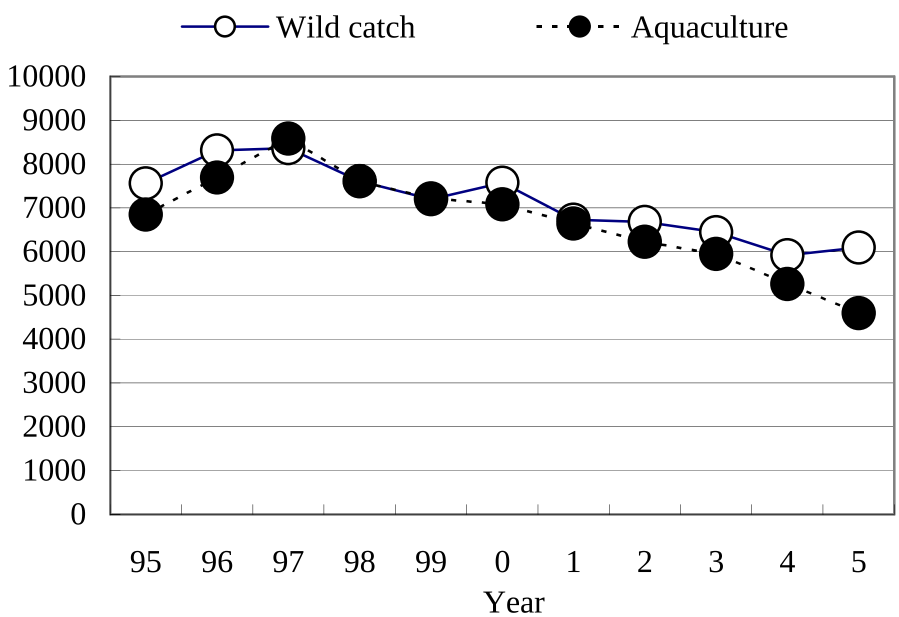

Fig. 1 Wild catch and aquaculture production of Japanese flounder in Japan (MT).

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Although the peak season for Japanese flounder is winter, this fish is eaten all the year round except for mid summer mostly as raw fish SASHIMI at Japanese restaurants including SUSHI bars. Suitable market size is 0.8 to 1.5 kg, and the price varies due to several factors including fish size, season, live or fresh, and location like other finfish species. The price calculated based on total aquaculture production and the sales throughout Japan have tended to decrease in recent years. However, this fish still has one of the highest commercial values and the price is 2 to 3 times higher than for yellowtail and red sea bream. At the Tsukiji fish market Tokyo, marketable size fish is mainly dealt, the price for live fish has been higher than 2000 Japanese yen (JPY)/kg from 2000 to 2007. Live fish is preferred in the Tokyo area and commands a higher market price.

This paper deals with the present status of commercial production of Japanese flounder in Japan, and also provides up-to-date information on the nutritional availability of dietary protein, lipids, and carbohydrates for grow-out of Japanese flounder.

Commercial production

Aquaculture of Japanese flounder has mainly been conducted in southern Japan due to good conditions for water temperature. Unlike other marine finfish species that have been produced with floating net cages, land-based culture tanks with running seawater (flow-through) are the prevalent culture system for flounder accounting for 75% of production area in 2005. There may be 300 to 400 farms producing about 16 MT fish a year each with an average of 1300 m^2 culture tanks or net cages throughout Japan.

Typical land-based flounder farms are located in seaside areas and consist of seawater intake pumps, sand filter system, culture tanks, and oxygen supply units. Culture tanks are generally installed indoors or are covered with shade cloth, as this fish is considered to prefer dimly lighted places (Fig. 2). Bottled oxygen and diesel generators are commonly installed for emergencies. Some farms have UV sterilizers for disinfection and a head tank for seawater storage. The culture tanks are constructed of various materials: concrete, fiberglass reinforced plastic, and plastic sheets with wooden frames. The most popular shape is a circular tank of 6 to 10 m diameter, but square or octagonal tanks are also used. Water depth in the tanks is 60 to 80 cm. Sand-filtered seawater is continuously supplied to the tank with 12 to 24 exchanges daily. The exchange rate depends on water temperature and stocking density. Culture water is drained from the center of the culture tank and discharged to the coast without treatment. Direct aeration in culture tank by surface aerators or diffusers with compressed air is conducted, and pure (liquid) oxygen is commonly used during the summer. Dissolved oxygen level is maintained at a minimum of 70% of saturation. A few farms cover tank bottom with sand to produce fish without abnormal coloration on the blind side that has extra market value (Iwata and Kikuchi 1998).

Fig. 2 Typical land-based flounder farms in Japan. Left: square shaped fish tanks made of concrete are installed in shade cloth house; corners of the tanks are rounded off to avoid stagnant water. Right: round shaped fish tanks made of fiberglass reinforced plastic; top of the tank is covered by vinyl sheet.

The production cycle differs from farm to farm, as fingerlings are available almost throughout the year. One to 3 g fingerlings obtained from commercial hatcheries are stocked in the culture tank at 100 - 200 fish /m^2 in winter to early spring. Fish grow to 0.5 kg in 9 to 10 months and 1 kg in 14 to 16 months. Stocking density increases with the growth of fish and is generally adjusted to be less than 15 kg/m^2 without oxygenation. The main shipping size seems to be 600 to 800 g, slightly smaller than the optimum size for market.

Fish are fed commercial pellet diet for the first few months, and are then fed moist pellet and raw fish. Locally available sand lance, sardines and horse mackerel are used as whole fish or ingredients for moist pellet. Total consumption of raw fish and dry pellet were 12447 MT (wet wt.) and 4519 MT, respectively, in 2005 for producing 4592 MT flounder. Feed efficiency as the fish grew from 9 g to 500 g on commercial pellet diet at 20°C is reported to be 100% (Honda and Kikuchi 1997), and the efficiency tends to decrease with the growth of fish. Higher feed efficiency was reported for raw fish (Morizane and Takimoto 1984), and efficiency of 120 to 170 g initial body weight fish fed sand lance or horse mackerel was 150 to 200% (wet/dry).

Survival throughout the culture period varies from farm to farm and ranges from 60 to 80%. There are several viral, bacterial, and parasitic diseases, such as rhabdovirus, edwardsiellosis, streptococcosis, scuticociliatidosis, and white spot disease. The damage by pathogenic disease was estimated to be 1.3 billion JPY in 2004 about 17% of the total value of flounder aquaculture. One of the most severe diseases has been edwardsiellosis accounting for 30 to 40% of the total damage every year by occurring frequently in summer. Rapid removal of infected fish, lowering water temperature and stocking density, increasing dissolved oxygen level, supplying vitamin rich diet and anti-biotic chemicals, and fresh water treatment are practical counter measures for the disease. Only three chemicals are registered for treatment of bacterial diseases of flatfish in Japan, and none for viral and parasitic diseases.

Availability of dietary carbohydrates

Although carbohydrates are one of the most important energy sources for domesticated farm animals, most fish species have a limited ability to utilize carbohydrates. Growth and feed utilization of juvenile Japanese flounder fed a diet containing glucose was lower than those of fish fed maltose, dextrin, and potato starch diets (Kikuchi *et al.* 1998; Lee *et al.* 2003), and tended to decrease with decreasing molecular weight of carbohydrate (Kikuchi *et al.* 1998). A marked increase in blood sugar level after feeding was observed in fish fed glucose and maltose diets in both studies similar to other fish species.

Growth of 4 g flounder fed diets with different levels of dietary potato starch and fish meal was the highest at 45 to 50 % protein level, however, protein efficiency ratio (PER) seemed to be independent of dietary composition (Kikuchi *et al.* 1998) (Fig. 3). Negative effects of increasing level of dietary wheat flour with concomitant decrease of fish meal on the growth and PER seemed to be stronger with the growth of fish (50 and 300 to 350 g initial body weight) (Kikuchi *et al.* 1992). On the other hand, similar feeding trials with dextrin and 13 or 23 g fish showed opposite results, and PER increased with increasing dietary carbohydrate level (decreasing protein) regardless of feeing regimes (satiation or fixed ration) (Lee *et al.* 2002; Kim *et al.* 2003) (Fig. 3). The optimum protein level for growth was estimated to be 48 to 50% with 16 to 18% of dietary dextrin in these studies. Increasing level of dietary dextrin showed positive effect on the growth and feed utilization for 4 g size fish even for iso-nitrogenous diets (50% protein) (Lee *et al.* 2003). Thus, availability of dietary carbohydrate differed by the source of carbohydrate, and dextrin may work as an energy source improving protein utilization in flounder culture (Kim *et al.* 2005).

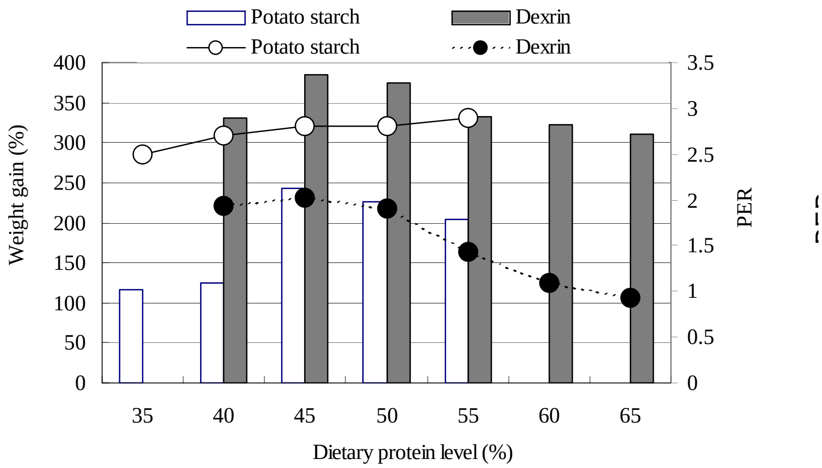

Fig. 3 Weight gain (bars) and protein efficiency ratio (PER, circles) of Japanese flounder fed diets with different levels of dietary carbohydrate and protein.
Figure was drawn based on Kikuchi et al. (1998) and Lee et al. (2002). Dietary potato starch and dextrin increased with decreasing level of protein (fish meal) in both studies.

Availability of dietary lipi

Utilization of dietary lipid as an energy source seems to be negligible or negative for the grow-out of Japanese flounder. Growth of 4 to 5 g fish fed diets with 6 protein levels (40 to 65%) and 3 lipid levels each (10 to 28%, pollack liver oil) generally depended on dietary protein level, and increasing level of dietary lipid did not produce positive effect at all protein levels when the fish were fed to satiation (Sato 1998) (Fig. 4). Furthermore, PER was statistically identical among dietary treatments regardless of dietary protein and lipid levels (Fig. 4). Negative effect of increasing dietary lipid on PER was shown regardless of protein level when 3 g fish were fed diets containing 30, 40, and 50% protein with 2 soybean oil levels each to satiation (Lee *et al.* 2000). On the other hand, a feeding experiment with lauric acid, and soybean, linseed and squid liver oils showed that growth and PER of 3 g fish depended on dietary fatty acid compositions (lipid source), and best growth was obtained for the squid liver oil group including highest C22:6n-3 (Kim *et al.* 2002). Availability of dietary pollack liver oil was examined with 55 g and 245 g fish, and PER of fish fed the diet with the highest lipid level (20.3%) was significantly higher than that of fish fed the lowest lipid diet (9.8%) in both feeding trials (Kikuchi *et al.* 2000). Utilization of dietary lipid by flounder may increase with the growth of fish, however, a large quantity of dietary lipid resulted in adverse effects on the health condition of the cultured fish by increasing blood triglyceride level, liver weight, and fat content of the liver and muscle (Sato 1998; Kikuchi *et al.* 2000). Although more information is required to clarify the optimum inclusion level of dietary lipid as an energy source, the potential utilization of dietary lipid by Japanese flounder is considered to be much lower than for Atlantic salmon *Salmo salar*, rainbow trout *Oncorhynchus mykiss*, or yellowtail.

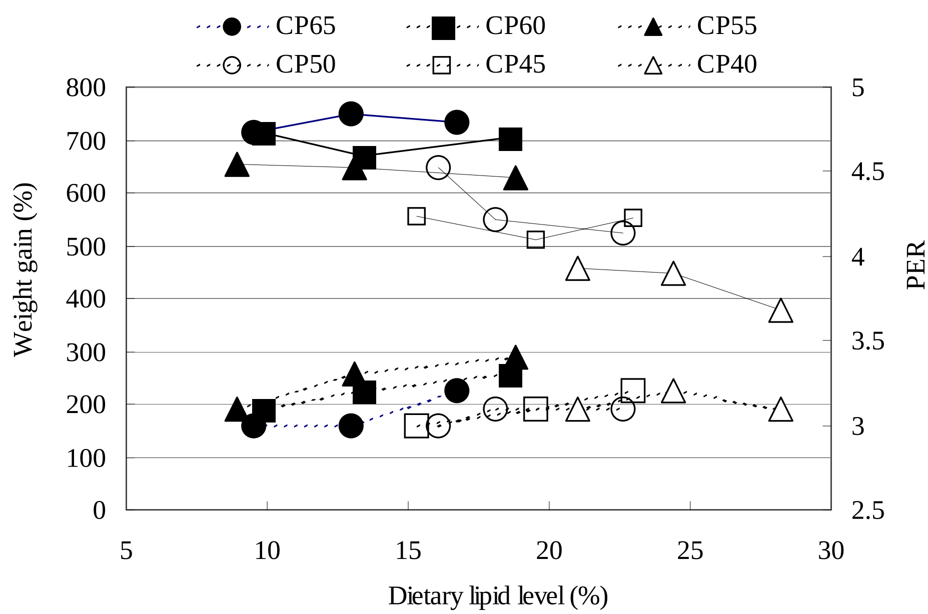

Fig. 3 Weight gain (solid line) and protein efficiency ratio (PER, dashed line) of Japanese flounder fed diets with different levels of lipid and protein.
Figure was drawn based on Sato (1998) .

Alternative protein sources for fish meal

Japanese flounder require a high percentage of protein in the diet. Because of the shortage of sardines that had been the main ingredient (protein source) in the formulated diet for fish in Japan, finding an alternative protein source is required to produce a stable supply of commercial diets at a lower price.

Soybean meal is a widely available economical protein source, and is considered to be one of the most suitable ingredients for replacing fish meal in commercial fish diets due to stable supplies. A preliminary study showed that nearly half of fish meal protein in the diet can be replaced with commercial defatted soybean meal (SBM) without adverse effects for 3 g flounder if the diets were supplemented with essential amino acids lacking in SBM (Kikuchi *et al.* 1994a). However, the fish fed the diet without supplementation had poorer growth. Reductions in growth and feed efficiency with increasing level of dietary soy protein concentrate for fish meal were reported without amino acids supplementation (Deng *et al.* 2006). Methionine is a typical amino acid with low levels in SBM, and inclusion of 1.5% in the diet was recommended (Alam *et al.* 2000). Pretreatment of SBM with an extruder and dietary inclusion of phytase seems to improve the nutritive value of SBM containing diet (Masumoto *et al.* 2001; Saitoh *et al.* 2003). Other studies indicated that 20 to 40% of fish meal protein can be replaced by feather meal (Kikuchi *et al.* 1994b), 20% by meat and bone meal (Kikuchi *et al.* 1997), 60% by meat meal (Sato and Kikuchi 1997), and 40% by corn gluten meal (CGM; Kikuchi 1999a) in the diet for juvenile Japanese flounder, and 20% by malt protein flour for fingerlings (Yamamoto *et al.* 1995) if crystalline methionine and lysine were appropriately added. Apparent protein digestibility of meat meal and SBM were comparable to that of fish meal, however, that of feather meal, meat and bone meal, CGM and malt protein flour was lower (Sato, 1998; Yamamoto *et al.* 1998) (Fig. 5). All essential amino acids of CGM were poorly available for Japanese flounder (Yamamoto *et al.* 1998).

A combination of SBM and blood meal successfully replaced 47% of fish meal protein in the diet without amino acids supplements (Kikuchi 1999b). Furthermore, substitution of blue mussel meat (5% dry matter) for an equal weight of SBM in this diet improved the growth of flounder markedly, mostly due to increased feed consumption. Stimulation of feeding with the mussel meat was demonstrated with a fish meal based diet in which 3% fish meal protein was replaced with mussel protein (Kikuchi 1998). Blue mussel meat is an effective protein source that can replace more than 60% of fish meal protein in the diet with incremental increases in growth and feed utilization without supplemental amino acids (Kikuchi and Sakaguchi 1997), although using blue mussel meat as the main ingredient of fish diet is far from practical. These studies revealed that large proportion of fish meal protein can be replaced by several alternatives in the diet of Japanese flounder. However, the results were obtained from few-week feeding trials with fish of less than 10 g initial body weight. Therefore, long-term culture trials are needed to address the practical use of these ingredients.

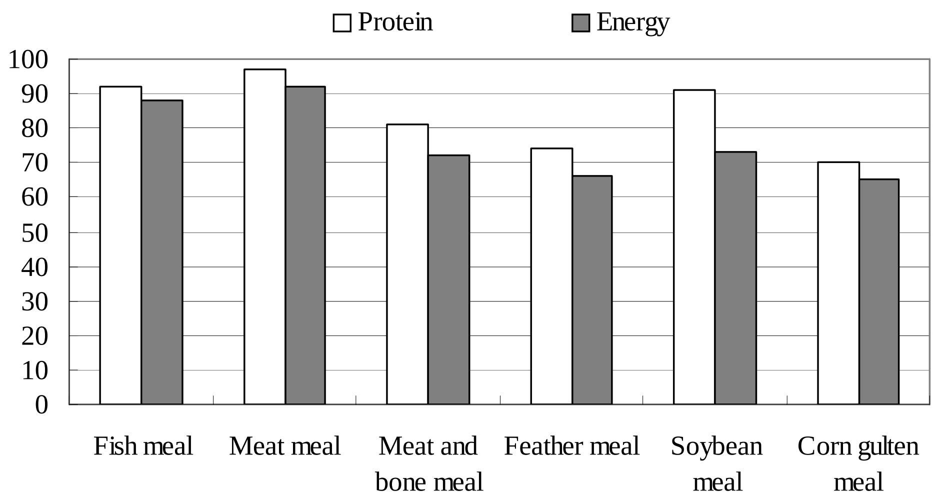

Fig. 5 Apparent digestibility of various ingredients Japanese flounder.
Figure was drawn based on Sato (1998).

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