**- Invited Paper -**

# STATUS AND PROSPECT OF ARTIFICIAL FEED FOR FISH CULTURE IN JAPAN

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In Japan, the culture of freshwater fish species such as rainbow trout (*Oncorhynchus mykiss*), carp (*Cyprinus carpio*), ayu (*Plecoglossus altivelis altivelis*) and eel (*Anguilla japonica*) has long been sustained by the use of several kinds of artificial feeds formulated depending on feeding habits, rearing techniques and nutrient requirements. On the other hand, until recently, marine fish species such as yellowtail (*Seriola quinqueradiata*), red sea bream (*Pagrus major*), flounder (*Paralichthys olivaceus*), greater amberjack (*Seriola dumerili*) and tiger puffer (*Takifugu rubripes*) have been fed frozen fish, like sardine. However, steam dry pellet (SP) and extruded pellet (EP) feeds have recently become popular also in the marine fish culture. Moreover, automatic feeders using SP and EP came into a wide use in the red sea bream culture.

This presentation is focused on the artificial feeds for yellowtail, which is one of the most important cultured fish species in Japan. Yellowtail culture has initiated in the 1950s, and expanded during the 1960s, keeping about 150,000 tons of its annual production thereafter. Until the 1990s, in floating net cages in the southwest of Japan, yellowtail mainly fed on minced and cut fishes such as sardine, sand lance and mackerel and grew up to 1.5 - 2.0 kg during 1 year of rearing period. However, since the feeding of frozen fish causes high water pollution around the farm area and facilitates the spread of fish diseases, from the 1970s members of the fish nutrition laboratory of Kochi University have initiated basal studies on the nutrition and feed formulation for yellowtail. In fact, the protein, fat, vitamins and minerals requirements of the species have already been elucidated. Based on these basal studies, Takeda et al. had found out that yellowtail fed Oregon moist pellet feed (OMP, mixture of frozen fish and formulated feed compound) grows as well as fish fed raw fish feed. However, based on the fact that OMP is unstable and therefore demands refrigerator or freezer to be stored, other kinds of feeds were investigated to solve this problem. Shimeno et al. reported a single moist pellet feed (SMP) without raw fish, and Watanabe et al. developed an extruded pellet feed (EP), which can include high amounts (around 30%) of lipid. Both SMP and EP showed similar growth rates and feed efficiencies as compared to fish meal feed without any adverse effect. After various examinations and

trials, nowadays EP is widely used in yellowtail culture in Japan, though frozen fish and OMP feeds continue to be used during cold winters, because the consumption of feed, especially dry feed, is markedly reduced at low temperatures.

The catch of sardine has dropped sharply from 1990, and since this fish is not only the main fish used as raw feed but also one of the unique sources of raw material for fish meal production in Japan, this situation has caused a strikingly increased necessity to find out cheaper alternative protein sources as substitute for fish meal in order to sustain a stable feed production. The search trials based on feeding experiments and chemical analysis indicate that dietary inclusion of each of many alternative proteins tends to depress the growth and feed performance as its level increases. The negative effects of an excessive inclusion of alternative proteins are probably due to poor amino acid profile, low digestibility and/or the presence of anti-nutrients such as trypsin inhibitor (TI), antigen and phytate. However, its inclusion at limited amounts shows a growth performance and hematological characteristics comparable to the control fish fed a fish meal feed. These findings have also indicated that defatted soybean meal (SBM), chicken meal, corn gluten meal, full-fat soybean meal and malt protein flour may substitute fish meal up to 20%, and SBM seems to be the most valuable alternative protein source from the viewpoint of the amino acid composition, production amount and cost.

Since the dietary inclusion of excessive amounts of a single alternative protein reduces growth and feed performance, and therefore it is not so much able to spare the expensive fish meal, continuously effects of the combined inclusion of SBM and other protein sources were investigate to decline more amounts of fish meal in feed. Dietary combination of 20% SBM and up to 20% of chicken meal, molt protein flour or corn gluten meal shows similar growth rates and feed performance to the fish meal feed. These results indicate that the inclusion of SBM in an adequate combination with abundant and cheaper protein sources can replace larger amounts of fish meal (around 50%) in yellowtail feed without any adverse effect.

Many plant proteins contain anti-nutrients and show low digestibility nature. Physical and chemical treatments of SBM were determined to improve its nutritive value. Chemical analysis shows that heating, washing and alcohol purification of raw SBM markedly decrease TI activity and antigen content, while hydrolysis and fermentation effectively improve the protein digestibility. Feeding experiments indicate that dietary inclusion of raw SBM results in weight loss, while inclusion of heated (commercial) SBM considerably improves the growth and feed performance, being slightly lower than that of the control fish fed a fish meal feed. Furthermore, dietary inclusion of purified (soy protein concentrate: SPC), separated (soy protein separate) or hydrolyzed (soy protein peptide) SBM significantly improves feed performance. These findings indicate that heating treatment is essential and alcohol purification is sufficient to validate the use of SBM in yellowtail feeds.

The effects of the supplementation of crystalline amino acids on the utilization of several alternative proteins were determined. The dietary supplementation of small amounts of Met and Lys markedly improves the utilization of SPC, showing growth rates and feed

performance similar to fish meal feed. On the other hand, for the improvement of corn gluten meal utilization, it is necessary to supplement many kinds (Lys, Arg, Trp and Met) of amino acids in large amounts, suggesting its unpractical use. The results of the last two experiments indicate that small amounts of amino acids must be supplemented to the mixture of several alternative protein sources, which should be formulated depending on amino acid composition.

In conclusion, feeding raw fish as well as OMP results in high water pollution around the farm area and facilitates the spread of fish diseases, resulting in a reduction of the production capacity. Therefore, it is important for the preservation and the sustainable development of fish culture in Japan together with Korea hereafter to develop and spread excellent artificial feeds formulated based on the fish physiology and nutrient requirements. The feed must possess properties such as high quality, being safe for both the fish cultured and human consumed, a strong tolerance to fish diseases, and a low discharge of dietary nitrogen and phosphorus into the environment as well as high growth rates and feed efficiency.