THE PRESENT AND FUTURE OF MARINE-FISH CULTURE IN KOREA WITH EMPHASIS ON DIETARY REGIME

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ABSTRACT

The present situation and future perspectives of marine-fish culture in Korea were discussed with emphasis on feeding systems. An increased living standard with industrialization over the last few decades has increased demands for high-quality fish, and opened a door for a new industry, aquaculture that was considered to be the only alternative to ocean fisheries production that was also decreasing over the same period. Flounder production through aquaculture has increased more than 20 times over the last five years. Fish farmers were not prepared technologically for the level of production and consumption did not follow the increased production. As a consequence, production costs remained high and market price for products decreased, and thus many farmers suffered in recent years. To improve marine-fish production and increase profit, we need to improve feed technology including larval feeding, search for a variety of culture species that are more suitable for our culture conditions, develop a new species by using recombinant-DNA technology and improve management and product-marketing systems. Demands for high-quality fish are expected to increase in the future. The only way to meet these increased demands is to increase production through aquaculture. Therefore, we should develop cost-effective marine finfish culture systems, e.g., reduced feed costs, preventive measures for diseases, low-cost facilities and their maintenance, etc.

INTRODUCTION

Marine fish (excluding shellfish) farming is relatively young in Korea. However, marine-fish production through aquaculture has rapidly increased in recent years and is expected to further increase in the coming years, indicating that aquaculture becomes an important part of the fisheries production. According to statistics published by the Korean Ministry of Agriculture, Forestry and Fisheries (KMAFF, 1993), marine fish production in 1992 amounted to about 4,600 tons (excluding shell fish), which is almost twice the amount produced in 1990 (2,600 tons). Major species are olive flounder (3,200 tons), Korean rockfish (670), yellowtail (290), groupers (249), red seabream (117). (Unofficial statistics suggests that flounder production in 1993 is over 10,000 tons). Despite this impressive growth in fish production, not much improvement has been noted in feeding systems; e.g., diet formulation, pellet preparation and feeding strategy.

Most fish farmers prepare moist pellet using 20 - 50% formulated powder feed and 80 - 50% frozen raw fish (horse mackerel, mackerel, etc.). With this feeding system, fish farms have faced many problems: feed waste, water pollution, disease outbreaks and consequently economical loss. To reduce these problems, we need to develop dry pellet diets for marine fish species such as flounder, yellowtail, rockfish and others. These species don't seem to have digestive system strong enough to break hard dry pellet and thus consume less feed when they are fed hard dry pellet, resulting in growth depression. Therefore, future research has to focus on developing extruded pellet diets that are soft and nutritionally balanced.

The objectives of this presentation is to discuss the present situation of marine-fish culture including brief history and address the problems and future perspectives for possible solutions.

PRESENT SITUATION

Aquaculture in Korea has rapidly increased in the 1980's as demand for live fish increased with the increased living standard, while fisheries production decreased due to decreased resources in the coastal sea. As a result, fish production through aquaculture has increased and more species have been added to aquaculture, necessitating to develop artificial feeding systems for new species.

Annual average water temperature of the Korean coastal sea is ranged from 5 to 27°C in East Sea, from 6 to 30°C in West Sea and from 6 to 28°C in South Sea. This extreme temperature range is not adequate for culture of migrating warm-water fish species, such as yellowtail, red seabream and flounder, especially during the winter season. Similarly, culture of cold-water fish species, such as salmonid, is difficult because the high temperature during the summer season. On the other hand, Korean rockfish, seabass and mullet have been resident fish in the coastal sea of Korea and maintain some growth at temperature ranging from 5 to 30°C, although relatively slow growth of these fish makes culture production less profitable.

In 1964 an attempt was made to culture yellowtail in net pens in East Sea without much success. In the early 1970's culture of yellowtail and red seabream has begun in the coast of South Sea by using net pens. During the early period, aquaculture technology was not fully developed, and thus fingerlings of those species were captured in the coastal ocean, fed for a short period and exported to Japan. In the late 1970's, with more experience some culture methods were established.

In addition to the decreased catch from the ocean, the higher living standard with increased GNP during the 1980's has increased demand for high-quality live fish. In 1986, cultured marine-fish production was 2,915 tons, 99.8% of which was yellowtail (Table 1) because it was easy to catch yellowtail fingerlings that grow relatively fast. However, culture during winter was impossible in most areas because yellowtail require warm water to grow. Therefore, they were produced during a short period when water temperature was high, demanding much frozen fish as a main feed source. High feed costs, and low market price (because products were marketed right before the winter started) made this aquaculture unstable and unprofitable. Supply of fingerlings was also unstable because catch varied from year to year. For these reasons, yellowtail culturists began to look for alternative species for culture.

Olive flounder were found to be a good candidate for culture, because flounder were relatively resilient in varying water temperature and disease outbreaks, and had high feed efficiency with an acceptable growth rate and a higher market price, and also artificial reproduction was possible without

Table 1. Marine finfish production in Korea (tons)

Species	1986	1987	1988	1989	1990	1991	1992
Yellowtail	2910	1418	1258	1569	462	893	287
Red seabream		106	4	129	228	361	117
Bass		70	1	98	391	377	249
Olive flounder		20	16	249	1037	1815	3199
Rockfish		85	3	96	386	312	666
Others	5	74	8	520	152	147	77
Total	2915	1773	1290	2661	2656	3905	4595

Adapted from Statistical Yearbook published by KMAFF (1993).

a need to catch fingerlings from the ocean. However, culturing flounder in net pens was impossible because of high mortality. Fish farmers moved culture locations from net pens to circulating tanks built inland. As a result, in 1992 flounder shared 70% of 4,595 tons (although the actual flounder production would be much higher than the official figure) of the total marine-fish production, while yellowtail production shared only 6% of the total. Recently, flounder culture in net pens has been increasing with improved technology. Along with flounder, culture of Korean rockfish, groupers, red seabream and mullet are currently increasing.

Current statistics on marine-fish farms is shown in Table 2. Most of the net pen-style farms are located in the southern coastal areas, where many small islands protect nets from typhoon. Fish farms with inland circulating tanks are located where clean salt water can be supplied: Southeast coast and Cheju. Dam-style farms are located in the southwest coast, where shallow sea is available.

Table 1 shows that yellowtail was a main culture species until 1986, but was replaced with flounder in recent years. There seems to be a potential for groupers and rockfish culture to grow. With a rapid growth in marine-fish

Table 2. Distribution of marine-fish farms

Province	Net-pen style		Inland tanks		Dam style	
	Number	Area	Number	Area	Farm	Area
		ha		ha		ha
Kyung-gi	2	4	-	-	19	225
Chung-nam	46	66	15	5	14	212
Jeon-buk	3	5	11	3	7	44
Jeon-nam	67	90	56	28	39	146
Kyung-nam	113	180	121	13	2	8
Cheju	7	8	95	45	2	5
Kyung-buk	44	49	67	23	15	19
Kang-won	6	5	22	10	-	-

Statistics adapted from K.R. Chun (1993)

culture, together with industrialization and urbanization, potential risks including outbreaks of diseases and red algae bloom from water pollution are increasing.

Because rapid increases in flounder production was not followed by increased consumption, the market price has decreased in the last three years. The decrease in the market price became a significant burden to flounder farmers, especially those running inland circulation tanks that require much higher production costs, as compared to net pen or dam-style operations.

Feed is a major contributing factor to fish production costs and also to limiting in marine-fish production because diets for marine fish require high-quality protein that is mainly provided with white fish meal and frozen raw fish which are not only expensive but also highly variable in supply, quality and price. The sources of frozen fish are horse mackerel, amber fish and mackerel and the catch of these fish is seasonal. Because these fish are used for human consumption, price is high except when the catch is in excess, and the quality is not warranted when fish are frozen after being collected from the retail market, where they are to be sold for human consumption. If there is surplus, then fish are stored frozen and sold for fish feed.

Diets used for most marine fish culture are prepared with frozen fish, and commercially prepared formulated feed, in which fish meal is a major protein source. Use of frozen fish makes fish production difficult and costly because the supply is not secured and fish farmers need large-scale freezers consuming much electricity, crusher, pelletizer and extra labor to prepare moist pellet. The use of frozen fish also increases feed wastage and deteriorates water quality. Increased rates of disease outbreaks due to the use of frozen fish necessitates the use of chemicals and antibiotics. All of

Table 3. Formulated fish feed production (tons)

Species	1987	1988	1989	1990	1991	1992	1993
Carp	22282	43830	70544	64032	54114	49953	52372
Rainbow trout	1656	6141	11338	10775	9613	10787	11793
Eel	5033	8446	11419	9997	15451	15953	14152
Others	152	672	650	5910	9996	9488	15229
Total	32123	59089	93951	90714	89179	86181	93546
Flounder			474	1529	3588	4795	6146
Other marine fish						1201	2391

Adapted from data collected by Inland Aquaculture Cooperative (1993).

these result in economical loss and water pollution.

The main reason for the use of frozen raw fish is that no commercial diets guarantee satisfactory growth of flounder, unless frozen raw fish is used. The fraction of raw fish in the moist pellet is usually between 0.5 to 0.9, when the ratio is expressed on an as-is basis.

Table 4. Composition of diets (%) - Experiment 1

Diet[1]	S	C1	C2	C3	C4	C5	C6
Fish meal	70.0						
Corn starch	16.5						
Squid oil[2]	10.0						
Vitamin mix[3]	0.5						
CM cellulose	3.0						
Choline chloride	0.7						
DM basis							
Crude protein	45.0	45.0	47.0	47.0	48.0	50.0	48.0
Ether extract	15.0	3.0	5.0	3.0	5.0	5.2	3.0
Ash	14.0	17.0	16.0	19.0	18.0	10.0	17.0

[1]S, Laboratory-formulated diet. C1 - C6, commercial flounder diets, ingredients of which were not clearly defined (closed formula). Diets were made into moist pellet after being mixed with 30% water and the moist pellet was frozen at -20°C until fed.

[2]Alpha-tocopheryl acetate (0.5 g/kg diet) was added to fish oil.

[3]Kim et al., 1991.

As shown in Table 3, formulated fish feed production has been decreasing since 1989 when about 94,000 tons of formulated feeds were produced. Most fish feed produced was for carp, rainbow trout and eel culture. Although the amount is small, formulated feed for flounder has increased from 474 tons in 1989 to over 6,000 tons in 1993. This figure proves that unofficial statistics on flounder production (10,000 tons in 1993) is realistic because (6,000/0.2)/3 is 10,000; where 0.2 is the ratio of formulated feed to frozen fish and 3 is feed as fed/gain ratio.

At our laboratory (Kim *et al.*, 1993), we tested a laboratory-formulated diet (Table 4), comparing with commercially formulated diets for flounder. Moist pellet was prepared from the formulated powder diets without using raw fish. The result showed that there are large variations in the quality of commercial diets, when growth and feed efficiency obtained with the diets

Table 5. Comparison of weight gain of Japenese flounder fed a laboratory-formulated (S) and commercial feeds (C1-C6) for four weeks[1] - Experiment 1

Diets	S	C1	C2	C3	C4	C5	C6	SE[2]
Gain[3]	26.5	18.7	15.4	17.5	19.7	20.3	20.6	2.3
Gain/feed[4]	1.08	0.89	0.60	0.87	1.13	0.87	0.77	0.10

[1]Values are means of three replicates of 20 fish each. Mean initial body weight ± s.e.m. was 42.1 ± 0.2 g for 21 tanks of 20 fish each.
[2]Pooled standard error.
[3]g live weight gain/fish.
[4]g live weight gain/g dry matter of feed.4g gain/fish fed S was higher than C2 or C3 (P<0.05).

were compared (Table 5), indicating that most of the commercial diets be improved in order to achieve better growth.

In a second experiment, we found that weight gain of flounder fed a 100%

Table 6. Composition of diets (%) - Experiment 2

Diet[1]	G	C6	Frozen mackerel
Fish meal	70.00		
Wheat flour	15.93		
Squid oil	10.00		
Guar gum	3.00		
Vitamin mix[2]	1.00		
Trace mineral mix[3]	0.05		
BHT	0.02		
DM basis			
Crude protein	48.9	48.0	67.0
Ether extract	15.0	3.0	26.3
Ash	14.0	17.0	6.0

[1]G, laboratory-formulated grower diet; C6, commercial flounder diet, ingredients of which were not clearly defined; frozen Pacific mackerel containing 70% moisture mixed with G or C6 (1:1 on an as-is basis).

[2]Grobig-fish (Bayer (Korea) Ltd, Seoul) supplemented with vitamins E nd C: As IU or mg/kg diet; vitamin A 5000 IU, vitamin D3 1000 IU, vitamin E 300, vitamin K 10, vitamin B1 20, vitamin B2 20, vitamin B6 20, vitamin B12 0.020, vitamin C 300, niacin 100, Ca-D-pantothenate 50, folic acid 5, choline chloride 550, biotin 0.10, inositol 100, paraaminobenzoic acid 10.

[3]As mg/kg diet; Zn 15, Mn 6.5, Cu 1.5, Co 0.05, Se 0.02,I 0.55.

laboratory-formulated grower diet (G), 50% G + 50% frozen mackerel and 50% commercial diet + 50% frozen mackerel (Table 6) for 6 weeks was 31.6, 29.4 and 27.5 g/fish, respectively (Table 7). This result suggests that

Table 7. Weight gain and feed efficiency of Japanese flounder fed 100% laboratory-formulated, 50% laboratory-formulated + 50% Pacific mackerel or 50% commercial + 50% frozen Pacific mackerel diet for 6 week[1] - Experiment 2

Diet	G	G+M	C6+M
Gain[2]	31.3 ± 0.8	29.4 ± 1.0	27.5 ± 1.8
Gain/feed[3]	0.53± 0.01	0.50± 0.14	0.49± 0.03

[1]Values are means ± s.e.m. of three replicates of 400 fish each. Mean initial body weight ± s.e.m. was 79.5 ± 1.0 for nine tanks of 400 fish each.
[2]g live weight gain/fish.

alternative feeding systems without using raw fish can be possibly developed.

Larval feeding of marine fish has been done by using live feeds, such as rotifer (*Brachionus plicatilis*) and brine shrimp (*Artemia salina*). Mass production of rotifers which also require chlorella as feed is an expensive part of marine-fish culture because it requires extra labor and facilities. Therefore, developing artificial feeds for larval feeding from the beginning is a necessary step toward cost-effective production.

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FUTURE PERSPECTIVES

To improve marine-fish production and increase profit, we should improve feed technology, search for different culture species that are more suitable for our culture conditions, develop a new species by using recombinant-DNA technology and improve management and product marketing systems. No doubt that larval feeding will remain as a limiting factor in marine-fish production and expensive part of a production cycle.

As aforementioned, the use of frozen fish add many problems to marine fish culture. Only alternative is to develop pellet diet (without using frozen fish) that are well accepted and utilized by marine fish while being economical. For example, flounder do not accept hard dry pellet and therefore we need to develop pellet which is soft (perhaps like marshmallow) and nutritionally balanced. This is not an easy task because pellet is hardened when dried after powder goes through the extruder and pellet die. During this process, much nutrients, especially vitamin C, are destroyed. In Japan (Watanabe *et al.*, 1991), so-called 'soft-dry pellet' has been claimed to work for yellowtail feeding. This pellet produced with twin screw extruder was compared with moist pellet prepared with frozen fish and formulated powder (8:2 ratio by weight). The growth similar in yellowtail fed either diet.

To reduce feed costs, we should also work on alternative sources of protein and energy to fish meal which is variable in price and quality as well as supply. More plant protein, fats and oils may be used for fish feed ingredients. Physical and chemical treatment of oil meals may improve the availability of protein and other nutrients. Removal or inactivation of harmful components, and extraction of protein can be done to improve feed quality of oil meals.

Little information on nutritional requirements of marine fish is available. With new species explored for aquaculture, there is a great need of research on nutritional requirements including dietary ingredients. This research area in Korea is far behind, as compared to other Asian countries, e.g., Taiwan, Thailand Philippines, Singapore, etc. Research institute for aquaculture (equivalent to National Research Institute of Aquaculture in Mie Prefecture, Japan) is recommanded to be established. Research fund specifically designated for aquaculture should be established.

In addition to the development of grow-out feeds, much effort should be given to the development of artificial diets for larval feeding of marine fish. Broodstock diets are also important in producing high quality eggs, which aid in survival and growth of newly hatched larvae. Consistency of diet quality is important for year-round production of eggs, which can be achieved by preparing artificial diets without using frozen fish. According to Watanabe (1989), the level of protein, phosphorus, essential fatty acids in broodstock diets influences spawning, egg quality and larval growth.

As consumers become more sensitive to the quality of products, we need to pay attention to diet formulation which may influence product quality. Many farmers of red seabream in Japan use pigments to improve product color. High levels of fat or rancid oil in diet may add greasy taste or fishy taste to products, respectively. This problem may be ameliorated by adding more antioxidants and vitamin E to diets.

Development of new culture species and breeding fish suitable for local farms through selection will improve productivity. Local resident fish species suitable for culture may be searched so that they may be used as a basis for produce new culture breeds in the future. Such species should be protected from being hybridized, as more and more exotic species are to be introduced with international open market currently being discussed under GATT.

Transgenic fish that grow fast or that can use plant feed sources more efficiently may be developed for culture. By adopting an integrated approach that encompasses improvements in hatchery technology and development, mass culture of superior quality brood stocks, application of recent advances in biotechnology and information, and advanced business management principles, it is possible to achieve higher targets, and, at the same time, being underused resources into optimal use.

Biotechnology is not a new field any more and is an assembly of new tools and technologies arising out of better understanding of biological systems and processes, particularly at the molecular level. Information technology has combined with two dramatic advances in biology, viz. recombinant-

DNA and hybridoma technology, to form the basis of the revolution in biotechnology. The distinction of this modern technology over the classical genetics or other analogous disciplines is the rapidity and molecular precision of its techniques. Transgenic prawns produced from eggs microinjected with a growth hormone gene fused with the promoter region of the MT-1 gene of flounder showed high concentrations of GH in body fluid, and grew significantly larger than normal prawns (Choudary, 1992).

To reduce production costs, we need to improve the present management methods. Designing feeding tanks is important to warrant efficient circulation, cleaning tanks and enabling us close observation of fish. Tank material plays a critical role in bacterial growth. Coating the tank surface may prevent bacterial colonization. With expected higher costs and scarcity of labor in the future, automation in feeding and cleaning may become a necessity. Computer-based operation in feeding, water supply warning systems, inventory and in and out schedule will soon become necessary for more efficient management.

Preventive measures or hygiene including vaccination should be expanded to reduce risk of disease outbreaks. To prevent bacteria-induced mortality, the current practice of adding antibiotics to water can be replaced by the addition of relatively less expensive but more reliable antibacterial substances derived from insects. The antibacterial peptides cecropins and attacins from species of silk moth offer good possibilities that the genes are introduced so fish may be more resistant to bacterial infections.

Selling of products has long been a headache for fish farmers because of the price bargain with intermediaries. Cooperative systems should be strengthened for fish farmers to be more competitive. Purchasing of supplies, selling products, planned production and product price control should be done through cooperatives. They can develop an integrated system, in which cooperatives provide seeds, feeds and technology, and buy, process and market products. Cooperatives can run retail markets or chain restaurants which specialize in fish menu. There is a need to develop a variety of products and menu for consumers. Advertisements is a necessity to increase consumption. Fish has become popular as a health food in recent years. New trade marks for products are needed to be developed, e.g., 'toco-flounder' grown on feed containing high levels of vitamin E (this will not only provide consumers with natural vitamin E, but also enhance shelf-life). Increased consumption will help produce more fish and increase market price. With all these improvements done, future aquaculture will rely on accessibility to clean water and its maintenance.

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