Present status and developmental trends of aquaculture nutrition and feed industry in China

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ABSTRACT: This paper presents a review of the development of aquaculture in China during the past 50 years. Core species composition in mariculture and freshwater culture in the year 2000 are shown and key trends are predicted. In addition, probable factors threatening the development of sustainable aquaculture in China are evaluated and areas of study for the near future are recommended.

In order to support a responsible aquaculture in China, modern biotechnology should be applied in areas such as genetic breeding, hatcheries, disease diagnosis and prevention, environmental protection and restoration, nutrition, feed, etc. This is especially true with aquaculture nutrition studies and the feed industry in China. Consequently, they are discussed in more detail. It is estimated that the gap between supply and demand of formulated feed in China's aquaculture is 12 million tons a year. Currently, large quantities of raw feedstuff and trash fish are used in aquaculture ponds and net cages annually. We, therefore, scrutinize the possible reasons China has lagged behind other developed countries in the areas of aquaculture nutrition and feed manufacturing and suggest the future directions of these important issues.

Keywords: China, Aquaculture, Nutrition, Feed industry, Developmental trend

1. OVERVIEW OF AQUACULTURE IN CHINA

1.1. Change of fisheries and aquaculture in the past 50-years in China

It is well known that China is a country with the longest history of aquaculture in the world. The earliest recorded aquaculture in China can be traced back to 2000 years ago. Fan Li wrote the first book on fish farming in China in 15th century BC. Why was China the earliest country to engage in aquaculture? Fish, together with other aquatic products, must have been very important dishes since ancient times in China. Naturally, people tried to find methods to provide fish regularly. There is a Chinese philosophical saying, "Give a man fish and he will have fish for one day. Teach him to culture fish and he will have fish for the rest of his life." Hence, the development of aquaculture in China has had both a practical and a philosophical basis from the very beginning.

Even though there have been thousands of years of aquaculture development in China, the percentage of aquaculture in the total fisheries production was very low before the 1950s due to the abundance of natural fisheries resources both in freshwater and marine, as well as the primitive farming methods in use with relatively low productivity. Since the late 1970s, aquaculture has increasingly become more important because of overfishing and environmental deterioration, particularly in a country like China that has a huge population burden. Figure 1 shows the changing trend of the total fisheries production and the proportion of aquaculture to the total fisheries production over the past 50 years in China.

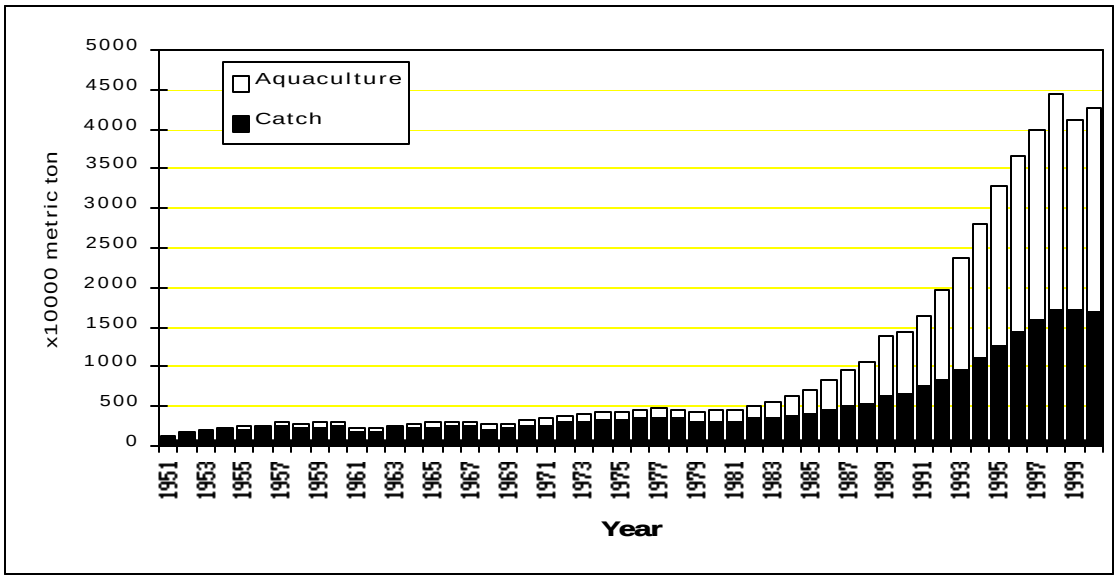

Figure 1. Fifty-year development of fisheries in China (1951-2000).

It can be seen from Figure 1 that aquaculture has been steadily increasing since 1970s, and sharply increasing since 1989. In the year 1988 the total fisheries production in China for the first time exceeded 10 million tons, and for the first time the percentage of aquaculture in total fisheries production was over 50%. So far China has still been the only country in the world, which aquaculture production is higher than capture production. Since 1993, the percentage of aquaculture has increased as high as some 60% of the total production.

1.2. Aquaculture production and main species of China in 2000

1.2.1. Aquaculture production - 2000

Aquaculture production of China in 2000 was 25.8 million tons, of which 15.2 million tons came from freshwater culture and 10.6 million tons from mariculture. The former accounted for 59%, and the latter accounted for 41%.

1.2.2. Freshwater production

The dominantly farmed species in freshwater are silver carp, bighead carp, grass carp, common carp, crucian carp, tilapia, white amur bream, black carp, Japanese eel, mandarin fish, Chinese river crab, giant river prawn, and soft-skin turtle (Table 1).

1.2.3. Mariculture production

There were 10.6 million tons of mariculture products in 2000 in China. However, 81.1% of it was molluscs and 11.3% seaweed. Fishes accounted for only 4% shrimp for 2.1% and crab for 1.2% (Figure 2). This means that most mariculture production came directly from natural productivity. The main species of marine fishes cultured in China are Japanese sea bass, large yellow croaker, Japanese flounder, red sea bream, black sea bream, red drum, turbot, cobia, mullet, puffer fish and groupers. The main species of cultured shrimp in China at present are *Penaeus chinensis*, *P. vannamei*, and *P. monodon*.

Species	Production (x1000 tons)	Percentage (%)
Silver carp & bighead carp	4842	31.9
Grass carp	3163	20.8
Common carp	2120	13.9
Crucian carp	1375	9.0
Tilapia	629	4.1
White amur bream	512	3.4
Black carp	169	1.1
Eel (Japanese and European)	161	1.1
Mandarin fish	99	0.7
Chinese river crab	232	1.5
Giant river prawn	97	0.6
Soft-shell turtle	92	0.6
Others	1677	11.0

Table 1. The major species of freshwater aquaculture in 2000 in China

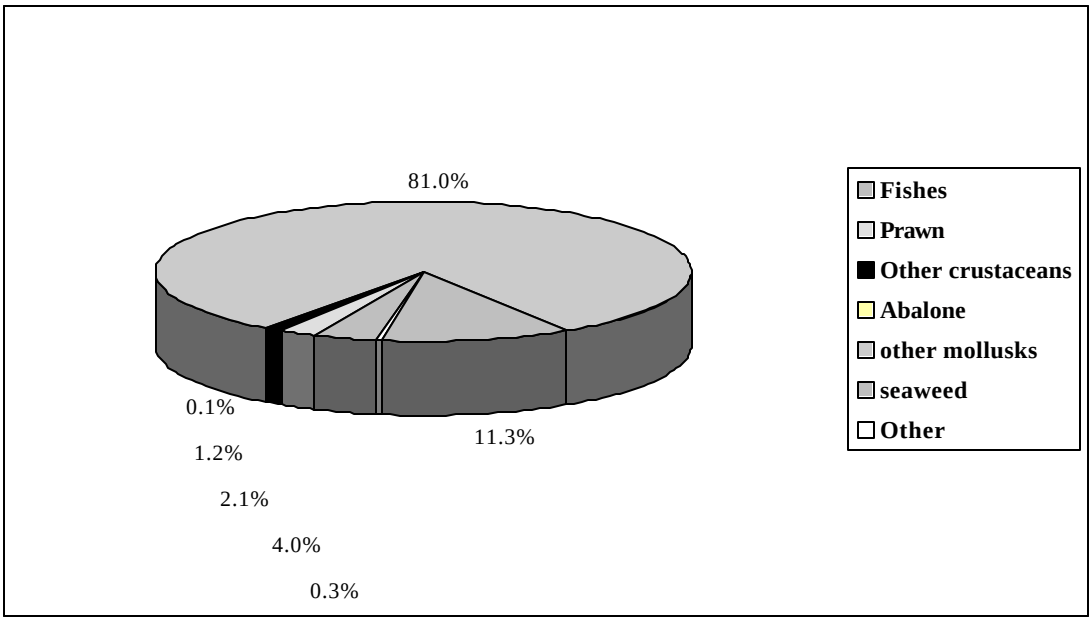

Figure 2. The composition of mariculture organisms in 2000 in China.

1.3. Problems and developmental trends in China aquaculture

1.3.1. Diversity of cultured species

One obvious characteristic of aquaculture in China is the diversity of cultured species and culture models. This is determined by the diversity of geographical environment of aquaculture, different developmental levels of productivity in different districts in China, and the eating habits of Chinese who always prefer to try something new. Little work has been done in genetic breeding and improvement for aquaculture species in China. People always like to introduce exotic species. Therefore, the diversity of cultured species and culture models will increase.

1.3.2. Low amount of mariculture production

Compared with the fish production in freshwater farming (14.8 million tons), the output (450,000 tons) of mariculture fishes remains very low. There are many reasons resulting in this difference in production totals between freshwater culture and mariculture in China. The history of marine fish culture in China is very short in comparison with that of freshwater culture. The methodologies and models used in freshwater culture probably cannot be copied directly to mariculture, and most marine wild fish probably cannot get used to the small ponds or cages used in freshwater culture. Limited supply of juveniles is a major factor restricting the development of marine fish culture because, so far, only a few species have been artificially spawned, hatched and reared successfully. Additionally, there is a much higher investment and risk of mariculture which are inhibiting factors in marine fish culture.

1.3.3. Traditional culture methods still widely used

Compared with the aquaculture industry in developed countries, aquaculture in China, including both freshwater culture and mariculture, is still traditional, scale-dependent, low technological value, and natural resource-consuming. These have been seriously threatening the development of sustainable aquaculture in China. In order to support a sustainable aquaculture in China, modern biotechnology should be applied in areas such as genetic breeding, improvement, hatcheries, disease diagnosis and prevention, environmental protection and restoration, nutrition, feed, etc. This is especially true with aquaculture nutrition studies and the feed industry in China. Consequently, they are discussed in more detail as follows.

2. AQUACULTURE NUTRITION AND FEED INDUSTRY IN CHINA

2.1. Classification of aquaculture species by feeding habits

It can be seen from Figure 3 that out of a total aquaculture production of 25.8 million tons in 2000, 52.1% is composed of filter feeders, 26.4% of omnivorous species, 12.3% of herbivorous, 4.7% of aquatic plants, and 4.5% of carnivorous species. Hence, the subtotal production of omnivorous, herbivorous and carnivorous species was 11.2 million tons. If all these species had been farmed using compound feeds, and the feed conversion ratio were 1.5, about 16.8 million tons of artificial feeds would have been needed. In 2000, however, there were only 5 million tons of formulated feeds produced for aquaculture, indicating that there is a gap of 12 million tons between supply and demand in aquaculture feed market in China. What supports the huge aquaculture production in China?

2.2. Major culture models and the status of formulated feed utilization

Freshwater culture in China mainly makes use of earth pond systems. Earth ponds are usually used for the common and cheaper species, such as various species of Chinese carps. There is also a small percentage of land-based tank systems and net-cage systems in lakes and reservoirs. These systems with higher investment are usually used for species fetching higher prices, such as eel, trout, sturgeon, soft-shell turtle, and other species of hard-shell turtle, etc. Most earth pond systems usually use fertilizers (either chemical fertilizers or manure) and directly feed raw materials, such as rice bran, wheat bran, rapeseed meal, peanut meal and soybean meal. Due to the huge farming area of earth ponds, however, 70% of the annual production of formulated feeds in China is consumed pond culture. The common species cultured by artificial feeds are grass carp, common carp, crucian carp and tilapia. Additionally, most net-cage and land-based tank systems use artificial feeds.

Crustaceans cultured in China are mainly marine shrimp, giant river prawn and Chinese river crab. Their cultivation usually utilises earth pond systems with high quality artificial feeds. Their feed conversion ratios

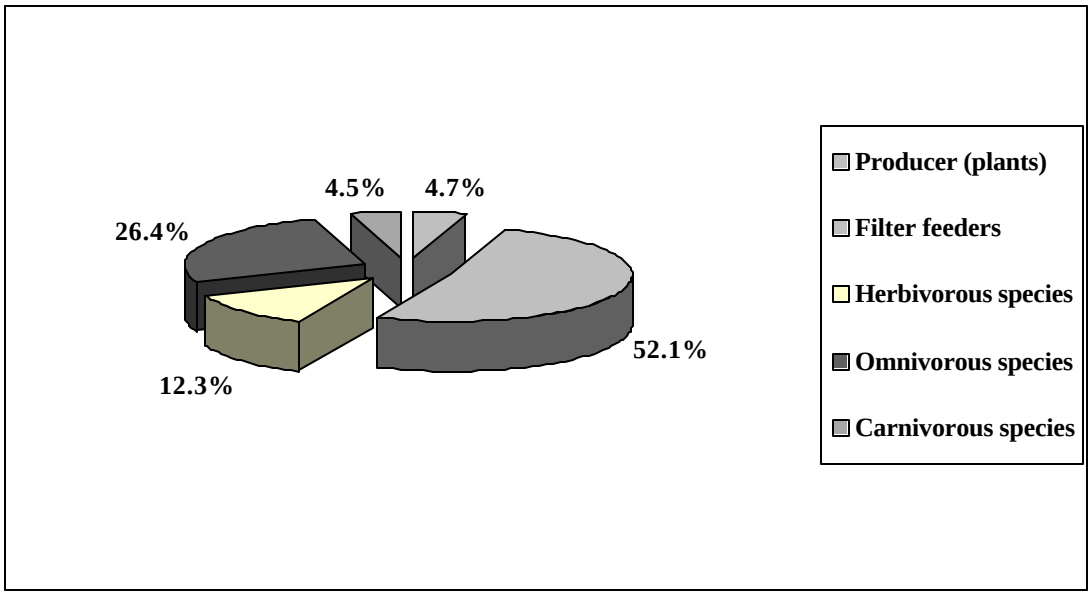

Figure 3. Classification of aquaculture species by feeding habit

are commonly between 1.2 and 1.6. High quality feeds have made an important contribution to the golden harvests of marine shrimp in recent years, particularly in the southern coast of China.

Marine fish cultivation in China usually employs net-cage, land-based tank and earth pond systems. Up to now, 90% of marine fish culture in China still uses trash fish feed.

According to an incomplete estimation, about 30 million tons of raw feedstuff and 4 million tons of trash fishes are directly used as feeds annually by aquaculture in China. This not only wastes a good deal of feedstuff resources, but also pollutes the aquaculture environment, and multiplies pathogens in aquaculture systems. If this serious situation is not changed, the sustainability of aquaculture in China will face a severe menace.

2.3. Present status of aquaculture nutrition studies and feed industry in China

A few studies on aquaculture nutrition in China started in the 1950s. However, extensive studies for feed industry applications started in the 1980s as the market demands for effective artificial feeds for shrimp and fish cultivation rose. Most work has been done on general nutrient requirements (such as protein, lipid and energy), digestive physiology, evaluation of the nutritional values of common feedstuff in China, and feeding trials for feed formulation selection. Limited studies have been conducted on the basic nutrition and micronutrient requirements of aquaculture animals. Freshwater species studied include grass carp, common carp, black carp, tilapia, white amur bream, Chinese river crab, crucian carp, Japanese eel, mandarin fish, giant river prawn, soft-shell turtle, etc. Among these, the species most intensively studied was grass carp. Marine species studied include shrimp, red and black sea bream, large yellow croaker, Japanese bass, Japanese flounder, etc. Intensive work has been done on the Chinese shrimp, *Penaeus chinensis*.

The results of these studies, together with the internationally published data, provide a basic reference for formulating commercial feeds for cultured species in China. Due to market demand, certain important ingredients used in aquaculture feeds, such as premixes of vitamins and minerals, stable vitamins, amino acid chelated trace elements, mixed enzymes, phytase, probiotics, prebiotics, etc., have been introduced, studied and produced in China. In the 1980s, the technology and machinery of feed manufacture were mainly introduced from

Taiwan, Europe and America. In recent years, the aquatic feed machinery has been made in China by joint ventures between Chinese and foreigners.

National, provincial and district centres of feed quality control have gradually been established to monitor and control the quality in nutrition, technique and hygiene safety of aquaculture feeds. A regular Symposium of World Chinese Scientists on Fish and Shrimp Nutrition has been held every three years since 1992, and a National Association of Aquaculture Nutrition Studies of China has been established since 1996. These activities strengthen information exchange and cooperation among the aquaculture nutritionists.

Figure 4 shows the changes in the numbers of aquaculture feed manufacturers, the annual production of aquaculture feeds and the percentage of aquaculture feeds to the total annual feed production in China during the period between 1991 and 1999. The aquaculture feed productions in 2000 was 5 million tons, and in 2001 was 6 million tons.

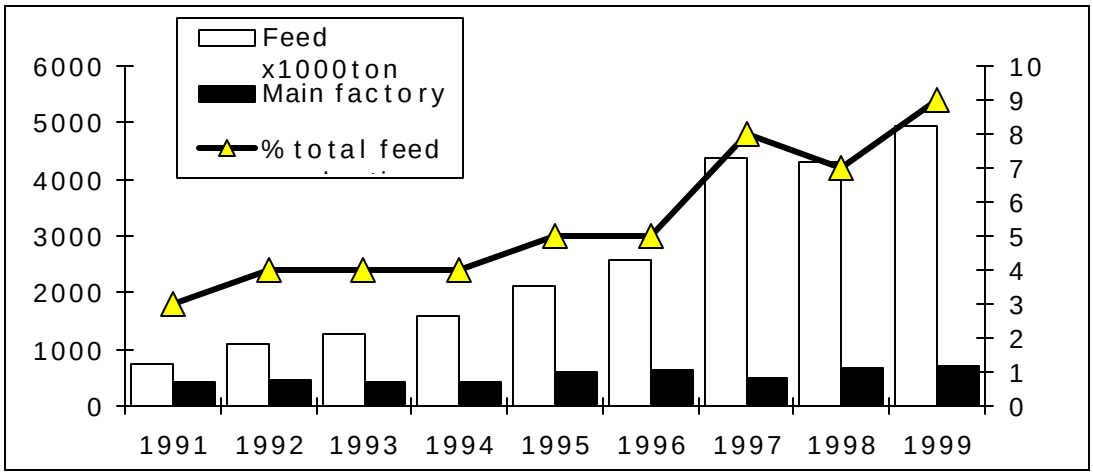

Figure 4. Manufactory, annual production and the percentage of aquaculture feeds to the total annual feed production in China between 1991 and 1999.

As mentioned before, the potential market capacity for aquaculture feed should be 16.8 million tons. Though the growth rate of aquaculture feed production in China is fast, obviously, there is still a huge gap between market capacity and supply. What are the problems hindering the development of aquaculture feed industry in China?

3. FACTORS HINDERING AQUACULTURE FEED INDUSTRY IN CHINA

3.1. Chinese feed industry a late development

China is a leading country in the scale of aquaculture, but not in feed industry. This agrees with the well-known fact that China is an agricultural country rather than an industrial one. Hence, as in many other industrial areas there are some similar reasons for feed industry not to be able to catch up the expansion of aquaculture. Studies on aquaculture nutrition started in China 40 years later than in developed countries. It was not until the 1980s that studies and feed development for aquaculture were brought into the national developmental plan of China.

3.2. Limited research funding

Fewer sophisticated scientists and limited governmental funding for studies on aquaculture nutrition and feeds certainly resulted in incorrect experimental designs, such as insufficient replicates for statistical analysis,

improper formulation, too short experimental period, etc. These weakened the reliability and utilization values of the experimental data. Even though many species cultured in China were studied concerning some aspects of their nutrition, these studies were unsystematic: there were many more general and macronutrient studies than basic and micronutrient studies.

3.3. Feed machinery and feed additives component

As in other industrial fields in China, the feed machinery and feed additives industries also lagged behind. Some components, such as some vitamins and amino acids, are still dependent on import. More importantly, the aquaculture feed market was/is undeveloped, and market behavior is not normative. Chinese farmers have the traditional laggard consciousness: large fish live on small ones who live on smaller shrimp, and shrimp on soil. They know that this is a food chain in nature. However, they still do not realize the crisis they are facing. Due to the use of raw materials and trash fish in large quantity as feeds in aquaculture systems, whatever they culture get diseases and probably mass mortality. Consumers psychologically reject the products because they may have the memory that some aquatic products with pathogens caused serious diseases in human, and some diseased animals looked disgusting. Hence, we still need time and education to popularize compound feeds in aquaculture.

4. DEVELOPMENTAL STRATEGIES OF CHINA AQUACULTURE FEED INDUSTRY IN FUTURE

4.1. Need for developmental strategies

As discussed above, we must eliminate the factors that hinder the development of aquaculture nutrition studies and feed industry. It is suggested that the following developmental strategies should be adopted.

4.2. Recommended developmental strategies

- Research methodology in aquaculture nutrition should be standardized in China. There should be a guideline for experimental designs. This purpose can be achieved by publishing a guideline book, training courses, and higher education to train an experienced term of aquaculture nutritionists.
- Systematic studies should be carried out on the nutrient requirements of the representative, commercially important and native species cultured in China, concentrating on a few representative species, rather than attempting to cover all cultured species, because of the limited research funding.
- High quality feeds that are suitable for different farming models and species in China should be developed to meet the market. Special attention should be paid to the development of nutritionally balanced feeds at lower nutrient levels for low priced fishes. At lower nutrient levels, fish probably do not grow as fast as at optimal nutrient levels. However, their growth rates and feed costs are acceptable from the economic point of view, and higher profits can be obtained. From this point of view, this nutrition should be known as "market nutrition".
- Because the aquaculture environment in China is deteriorating sharply, environmental nutrition studies and environmentally friendly feed development should be put on the research agenda. Studies should be conducted to improve pellet quality, and on the utilizations of exogenous digestive enzymes and phytase to increase feed digestibility. More importantly, phytase with neutral optimal pH is more useful for Chinese carps that usually have no stomach and neutral digestive liquid. Studies and development of feeds with low protein (especially low fishmeal) and high energy should be carried out to reduce the pollution of nitrogen and phosphorus from uneaten feeds and feces. To improve the aquaculture environment and the animals' health, probiotics and prebiotics should be exploited.

- Due to ocean environment deterioration and overfishing, an increasing lack of fishmeal is unavoidable. Hence, it is farsighted to exploit new protein sources to replace fishmeal in artificial feeds as much as possible for aquaculture. This is particularly important for China, which has the largest scale of aquaculture in the world, but only limited fishmeal production (about 200000 tons a year). At present, China has to import 1.5-2.0 million tons fishmeal a year for feed industry. If annual production aquaculture feeds reaches 16.8 million tons as calculated above, 4.05 million tons of fishmeal will be needed as estimated in Table 2. To meet such a high level of fishmeal demand is impossible. Therefore, reducing fishmeal level in feeds and exploiting new protein sources are the only way for sustainable aquaculture in China. Furthermore, considerable use of non-fishmeal protein sources definitely reduces the palatability of the feeds. Hence, not only the balance of essential amino acids but also effective feed attractants should be considered.

Feeding habits	Production Mt	Fishmeal in feed %	FCR (Supposed)	Fishmeal needed (Mt)
Carnivorous	1.16	40	1.5	0.70
Omnivorous	6.81	25	1.5	2.98
Herbivorous	3.17	8	1.5	0.38

Table 2. The potential annual demand of fishmeal for aquaculture feeds in China (based on the aquaculture production in2000)

5. CONCLUSIONS

In the past, we were always in pursuit of quantity rather than quality. With today's improvement in people's standard of living, those Chinese who are better off are now starting to seek after better quality foods. However, quality is not only concerned with food colour, flavour, taste and texture, but also with nutrition hygiene and safety. Consequently, research and development of nutrition and feed for aquaculture should shift from quantity to quality. In particular, after we have joined WTO, product quality should be put in the first place. Studies should be conducted on proper feed formulations, farming strategies and culture environmental management to improve product quality, on immune stimulants or enhancers to reduce the use of antibiotics, other harmful chemicals and their hangover etc.

Chinese farmers pursue higher profits in aquaculture than those in developed countries. Even though the labour cost in China is much lower than in developed countries, the price of high quality feeds is similar or even higher than that in developed countries. For example, the price of shrimp feed is slightly higher than that in the United States because the main feed components, like fishmeal, vitamins and other expensive additives, depend on import. More importantly, the main cost of aquaculture in China comes from its higher risk due to the deteriorating environment and frequent natural disasters that sometimes cause complete loss. Hence, improvement and restoration of aquaculture environment, precise forecast of natural disasters can reduce aquaculture risk, and subsequently cut down its cost. The control of the expansion of scale of aquaculture in China today is essential for environmental protection and restoration, by establishing a license system based on the carrying capacity of certain water areas. The feed cost can also be cut down by proper formulation, increasing production scale and product diversity per factory, and reducing management cost.

This is an important way to strengthen the cooperation between feed enterprises and research institutes and universities inside and outside of China.