



Review Article

Analysis of the Development of Snakehead (*Channa argus*) Industry in Shandong, China and Comparison with the Substitution of Forage Fish with Compound Feed

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Authors' Contribution

CL and JC wrote and revised the manuscript. TX analyzed the results. LZ, XY, YX and LL revised the manuscript.

Key words

Channa argus, Compound feed, Forage fish, Status analysis, Shandong

ABSTRACT

Snakehead (*Channa argus*), with high nutritional and medicinal value, is a traditional high quality edible fish. As one of the special and commercial cultured fish in Shandong province, China, snakeheads play critical role in promoting the economic development of fisheries. However, the sustainable development of snakehead culture industry has been seriously impeded cause the forage fish as main sources of baits. This study reviewed the current situation of snakehead culture in Shandong, compared the advantages and disadvantages of feeding forage fish and compound feed for snakehead culture. In addition, the development status and trend of compound feed for snakehead were analyzed. This review will provide insights into the green aquaculture development and industrial upgrading of snakehead in Shandong, China.

INTRODUCTION

Channa argus, commonly known as black fish or snakehead fish, as a representative fish of genus *Channa* in the family Channidae, is naturally distributed in

freshwater rivers and lakes in Asia, and is one of the most common freshwater cultured species (Liu *et al.*, 2010). With its delicious taste, high nutritional value, and blood nourishing and medicinal properties, snakehead has been regarded as a traditional famous cultured fish in China. In addition, snakehead also has great potential economic value in aquaculture, due to its fast growth rate, high disease resistance, and tolerance to poor water quality (Zhang *et al.*, 2020). In China, snakehead aquaculture is mainly concentrated in Guangdong, Shandong, Hunan and other provinces. In recent years, the production of snakehead reached more than 450,000 tons, with a yield of special and commercial fish. Shandong is an important area for snakehead aquaculture, and Weishan area of Jining city is known as the hometown of snakeheads in China

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(Tian *et al.*, 2019), and snakehead culture has gradually formed a large scale in Shandong and developed into a stable provincial specialty fish culture industry.

As snakeheads are carnivorous fish, snakehead culture is highly dependent on feed consisting mainly of juvenile forage fish or animal raw materials (Zhang *et al.*, 2017; Xu *et al.*, 2017; Li *et al.*, 2021; Zhao *et al.*, 2016). In recent years, with the massive demand for forage fish, rising prices and ecological problems caused by overfishing and feeding of forage fish. It is critical to develop suitable feeds for snakeheads to improve the nutritional value of feed, and reduce the feed conversion ratio for the sustainable development of snakehead culture industry (Fang *et al.*, 2019). In this paper, we systematically introduced the development statement of snakehead culture industry in Shandong, and summarized the advantages and disadvantages of different feeding feeds in snakehead culture industry. In addition, the development trend of compound feeds for snakehead was analyzed. In short, this study will shed light for the high-quality and healthy development of snakehead culture and its compound feed industry in Shandong.

STATUS OF SNAKEHEAD INDUSTRY IN SHANDONG

Output and aquaculture scale

The production of snakehead in China was decreased from 2015 to 2019. While the production of snakehead was rebounded slightly in 2020, and it was about 501,100 tons. The farming scale of snakehead in Shandong contracted from 2015 to 2020, and the area of snakehead culture in the province was 21,332,200 square meters in 2020. The production of snakehead in Shandong was also decreased, and the total snakehead production in the province decreased from 10.01 million tons to 38,600 tons in 2020 at a decrease of 61.4%. In 2020, the production of snakehead in Shandong province accounted for 7.7% of the total production of snakehead in China, second only to Guangdong (Figs. 1, 2).

Distribution of aquaculture area

Snakehead aquaculture is widely distributed in Shandong province, except for the city of Jinan, Dongying, Zibo and Weihai, and the remaining 12 cities have snakehead aquaculture industry. As of 2020, the production of snakeheads in Weishan area of Jining city reached 22,500 tons, accounting for 58.4% of the total production in Shandong, and ranked the first in the province. The production of snakeheads in Dongping of Tai'an city is second only to Weishan, with 10,200 tons, accounting for 26.5% of the total production (Fig. 3). The

layout of snakehead aquaculture industry in Shandong is relatively concentrated, with a high level of industrial aggregation. Although the production of snakehead in Weishan was decreased by about 24%, Weishan as the main production county of Shandong, is still an important distribution center for snakeheads in China (Cao *et al.*, 2021).

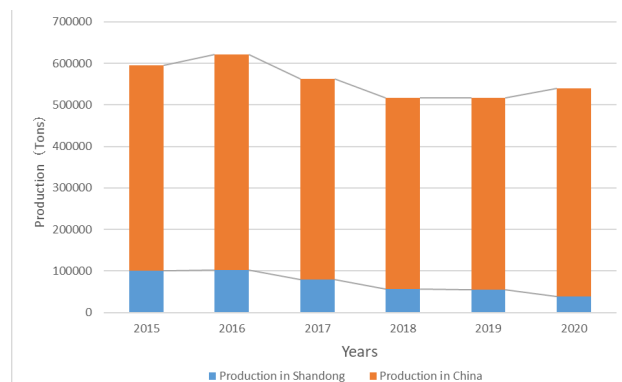


Fig. 1. The production statistics of snakehead in Shandong province and China from 2015-2020.

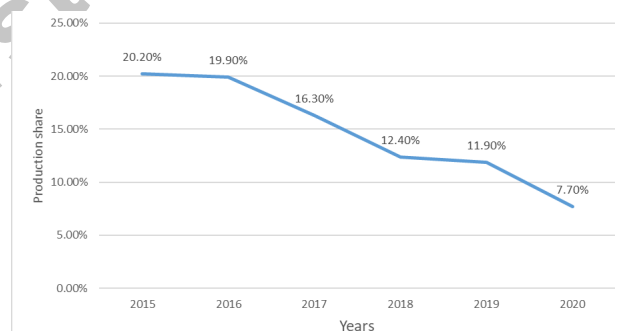


Fig. 2. Variation of the snakehead production in Shandong from 2015 to 2020.

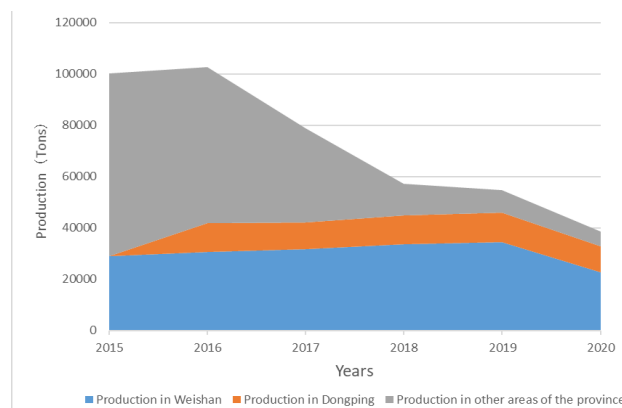


Fig. 3. Production trend of snakeheads in Shandong from 2015-2020.

Current status of aquaculture

Fry

The main source of snakehead fry in Shandong is a small town called Luqiao, Weishan county, Jining city, where 78.2% of the town's cultured snakehead fry are self-propagated and self-breeding for pond-bred snakeheads. 21.8% of the fry are relying on lake fish breeding of wild snakeheads in Weishan lake. The local hybrid fish fry is produced by crossing snakeheads in Weishan lake with snakeheads in the southern of China. The hybrid fry is bred in the south and then returned to Weishan for coarse marking, and then sold to all the cities of China. At present, Weishan county has established an efficient snakehead fry breeding system with a virtuous cycle of parental screening artificial breeding fry breeding fry breeding adult rearing (Wang *et al.*, 2012).

Aquaculture mode

Snakeheads are mainly cultured in ponds in Shandong, and the yield of ponds is more than 330 kg/acre. The culture of snakeheads is divided into seed breeding and adult fish breeding, and the normal breeding cycle is 2 years. In order to avoid the market impact of the southern hybrid snakeheads, snakehead culture in Shandong is mainly divided into two models: One is to buy large-size fry (3-4 taels/tail), in October of the year sell into the market; the second is to use a two-year breeding cycle, the following year before October sell into market.

Feeding

At present, the snakehead is cultured with compound feed, frozen forage fish and animal raw materials single feeding or mixed feeding. The animal raw materials are cheap and fed in larger quantities, but they are easy to cause red meat and affect the sales of adult fish. The frozen forage fish are mainly from coastal areas such as Jiaodong, which is the most widely fed feed for snakehead aquaculture. Although the main production areas of snakeheads, mainly in Weishan, have carried out technical exploration of snakehead domestication using compound feed (Tian *et al.*, 2022). The local enterprises and fishermen still believe that compound feed cannot completely replace forage fish, considering factors such as poor palatability and slow growth rate of compound feed.

Diseases

The snakeheads have a strong resistance to diseases, with little or no disease in the conventional culture state. However, there still has the possibility of disease outbreaks due to improper culture management and other factors, resulting in serious economic losses. The common diseases of cultured snakeheads mainly include water mold disease

and epidemic ulcer syndrome caused by fungal infection; nodular disease, hemorrhagic septicemia, rotten skin disease, ascites disease of snakeheads caused by bacterial infection; popping virus disease of snakeheads caused by viral infection; parasitic diseases caused by wheel worms and cucumber worms (Li *et al.*, 2018).

THE ADVANTAGES AND DISADVANTAGES OF DIFFERENT BAITS TO SNAKEHEADS

Forage fish

At present, snakehead culture in Shandong province still uses frozen forage fish as the main feeding food, accounting for about 70% of the culture industry (Liu *et al.*, 2016), and most of the forage fish come from the sea in the coastal area of Jiaodong. The feed conversion ratio of forage fish from sea is 5.5-6.0, which can make the maximum yield of 37,500-45,000 kg/hm² (Kong *et al.*, 2020). Moreover, the water temperature in Shandong is low in spring and snakeheads eating late. The local culture habit is that snakeheads generally do not overwinter so that the fish can reach marketable size within only 5 months of growth period. Therefore, forage fish is more suitable for snakehead culture in Shandong province, which can increase the growth rate of snakeheads and improve their physiological traits (Kong *et al.*, 2021). In addition, some studies have shown that feeding frozen forage fish can enhance the unsaturated fatty acid content of snakeheads (Giannenas *et al.*, 2012). The main snakehead fish farmers in Shandong are still reluctant to give up the use of forage fish, and this brings many problems and risks. The first and most serious problem brought by the long-term feeding of forage fish is water pollution. Most of the snakeheads are farmed at high density, and the feeding of forage fish makes a large amount of nitrogen and phosphorus in the water, coupled with frequent water changes during the aquaculture cycle, making the water seriously polluted. The emissions of nitrogen and phosphorus during snakeheads culture are much higher than the national standards for freshwater aquaculture effluent (Cui *et al.*, 2020). Secondly, the nutrient composition of forage fish is single, and the feed conversion efficiency is low. It takes about 5 kg of forage fish to raise 1 kg of commercial snakeheads fish. There is no uniform standard to ensure the safety of forage fish, because they have a wide range of sources. At the same time, forage fish are main source of pathogens, accelerating the spread of diseases and failing to ensure the quality and safety of commercial snakeheads. The forage fish are often the carrier of many pathogens. Improper cleaning, storage or feeding will easily cause disease outbreaks, cause liver and digestive tract problems, and affect the breeding efficiency of snakehead (Wang *et al.*,

2019). In addition, forage fish feeding also determines the provincial snakehead aquaculture industry cannot get rid of the small farmer operation method, also cannot improve the stocking volume. The forage fish feeding is vulnerable to price and fishing moratorium, and the market fluctuates greatly. The harvesting of wild juvenile forage fish has also produced incalculable damage to fishery resources. In a word, the long-term use of juvenile forage fish as feed has severely limited the development of snakehead aquaculture industry in Shandong province.

Compound feed

As early as the beginning of this century, some scholars tried to develop snakehead compound feeds to replace the feed of forage fish, and achieved fruitful results. In south China, for example, as the main production area of hybrid snakeheads, almost of breeding enterprises in the aquaculture process are completely using compound feed. The usage rate of compound feed in Guangdong province has reached more than 95%. This method has led to a significant increase in the production of hybrid snakeheads, making Guangdong province the top of snakehead production in China (Zhou *et al.*, 2017). It can notice that the efficient use of compound feeds can substantially increase the production of snakeheads. It also suggests that the dependence on the feeding of forage fish in Shandong is an important factor limiting the development of snakehead aquaculture industry.

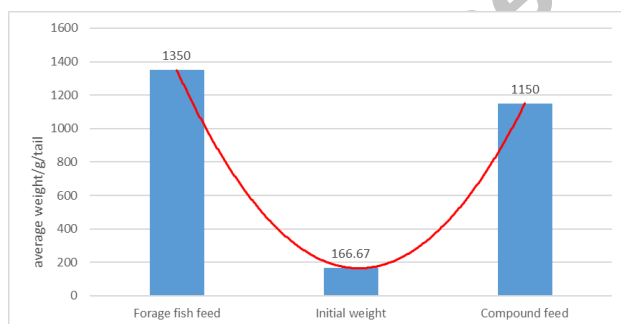


Fig. 4. Average weight of snakehead fish fed on forage fish feed and compound feed.

At present, some farmers in Shandong province have also started to use compound feeds instead of feeding forage fish for snakehead culture. According to the survey, compare with the feeding of forage fish, the use of compound feed can make the average weight of commercial fish reach more than 1.15kg (Fig. 4). Commercial feed-farmed snakeheads were able to be sold in the same year, but their average weight was slightly lower than that of feed- forage fish-farmed snakeheads.

In addition, the compound feed has good palatability, which can reduce the loss during feeding and significantly reduce the bait coefficient, with the lowest feed coefficient reduced to 1.07 (Fig. 5). Compound feeds are processed with various active substances according to the needs of feeding attraction, nutrition, disease resistance, stress resistance, and digestion promotion. Compared with the feeding of juvenile forage fish, compound feed can increase the survival rate of snakeheads by more than 10% (Fig. 6). Analysis from the environmental protection point of view showed that the feeding of compound feed could reduce the emission of nitrogen and phosphorus by 51.86% and 62.16%, respectively (Fig. 7). In turn, the discharge of nitrogen and phosphorus can reduce water pollution, which also makes the possibility of widespread disease outbreaks in cultured snakeheads significantly reduced, and has the relative advantage of environmental benefits. Finally, compound feeds have a wide range of raw material sources, which can reasonably develop resources. Furthermore, the rapid development of compound feeds has led to better feed production processes, easier transportation and lower costs. The analysis found that compound feed can save about 20% of bait cost per kg of commercial fish (Fig. 8).

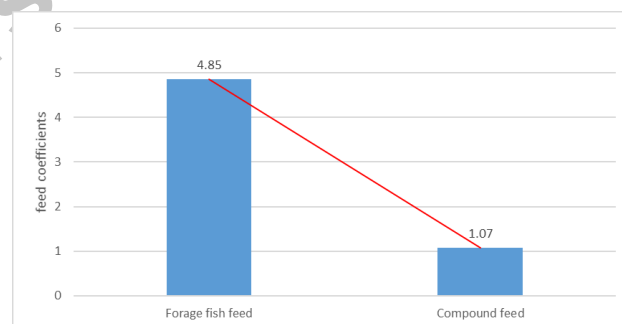


Fig. 5. Feed coefficients of forage fish feed and compound feed.

Despite the many advantages of compound feeds, there are still technical difficulties in the domestication of snakehead fry with compound feeds. The use of some low-quality compound feeds may make it difficult for snakeheads to grow beyond the bottleneck of 7-8 taels, and may also lead to a high rate of deformities in snakeheads, which affects the value of commercial fish (Jia *et al.*, 2010). The aforementioned two points have not been completely solved yet, resulting in the use of compound feeds by farming subjects still have greater doubts. The promotion rate of compound feeds in Shandong is not high, and farming enterprises are reluctant to try easily.

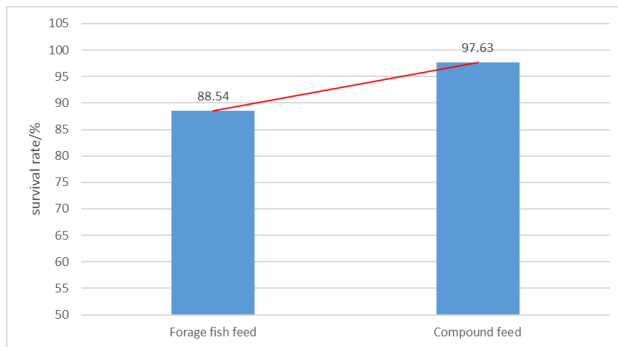


Fig. 6. Survival rate of snakehead fed on forage fish feed and compound feed.

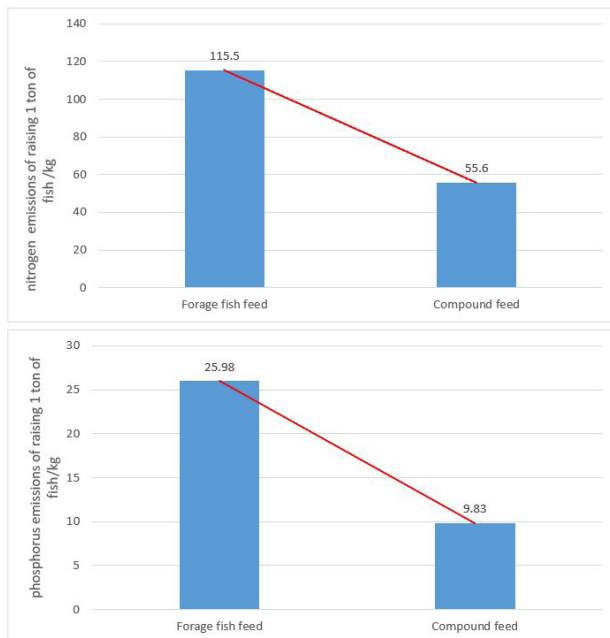


Fig. 7. Effect of forage fish feed and compound feed on nitrogen and phosphorus emissions by snakehead.

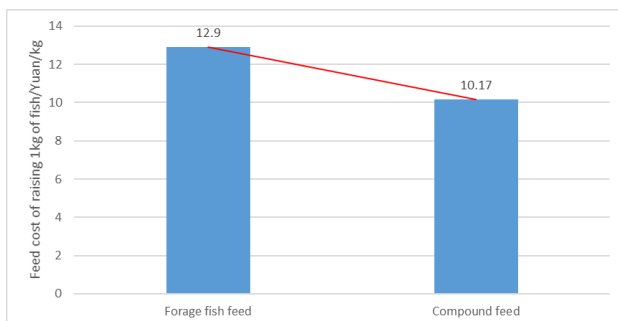


Fig. 8. Comparison of cost of forage fish feed and compound feed for raising 1kg snakehead fish/yuan/kg.

TRENDS OF COMPOUND FEED INDUSTRY FOR SNAKEHEAD

In recent years, ministry of agriculture carried out five major actions of green and healthy aquaculture. Shandong province, relying on the special action, developed a special program on the development of sea or freshwater aquaculture industry. The special work of snakehead aquaculture industry is to enhance the germplasm resources, ecological breeding and with compound feed to replace forage fish. This work is good at promoting the healthy development of snakehead aquaculture industry in Shandong province. At present, the province is gradually promoting the concept of snakeheads with feed to replace forage fish, which provides an opportunity for the development of the feed industry, as well as give a clear direction for the future development of feed.

The development of snakeheads with feed industry needs to be combined with the regional characteristics of Shandong province. It is urgent to improve the suitability of snakeheads' compound feeds, and at the same time to develop compound feeds applicable to the culture cycle of snakeheads according to the actual needs of snakehead culture in Shandong.

The compound feeds should be designed and adjusted for the growth cycle of snakeheads. The development of open feeds should focus on nutritional ratios and processing methods. The fry feed should be accurately quantified to ensure the quality of fry, and the domestication process should be standardized to ensure the reasonable use of feeds. The feeds in the middle and late stages of breeding should focus on nutritional value, conversion efficiency, cost of use and many other elements.

The most important point of compound feeds to replace forage fish is to respond to the requirements of environmental protection. The use of commercial feed is conducive to reducing the production of tailwater pollutants, thus achieving the purpose of green ecology and quality assurance of healthy breeding.

The development of compound feed should focus on functionality, especially under the premise of a comprehensive ban on the abuse of antibiotic drugs. It should be adjusted with the nutrient material of the feed, design new green functional feed. In the process of meeting the normal growth needs of snakeheads, it's important to improve the disease or stress resistance, and also improve the nutritional value and quality of snakeheads.

Another trend for compound feed in snakeheads is the source of key protein elements, which should be screened, developed more high-quality protein sources to improve feed utilization and enhance the quality of commercial fish.

The industry standard and quality supervision system of feeds for snakehead should also be established gradually to prevent uneven and inferior snakehead feeds in the market. This measure is good for the healthy development of the feed industry.

CONCLUSION AND RECOMMENDATIONS

The development of snakehead aquaculture industry in Shandong province is rapid and stable. However, with the attention of government departments to the problem of aquaculture tailwater pollution, the concept of green and sustainable development should be continuously promoted. The traditional feeding of forage fish is no longer applicable to snakehead culture. The replacement of forage fish with compound feed has become the top priority for industrial upgrading and the key to intensive and large-scale clean culture of snakehead in the future. Based on this, the following suggestions are made for the development of the feed for snakeheads: (1) To carry out in-depth basic research on the physiological characteristics of snakeheads, starting from the nutritional and growth requirements, nutritional values, and regional characteristics, so as to lay the foundation for the research and development of feed for snakeheads. (2) To increase the research and development of new feeds for snakeheads, to clarify the nutritional and metabolic characteristics of feed for snakeheads, to break through the technical bottleneck of feed for snakeheads, and to develop green, efficient, disease-resistant, and ecological feed. (3) Pay attention to the promotion of the use of feed with the focus on the main production areas of snakeheads such as Weishan County. To set up the promotion of the use of demonstration areas, with the domestication of snakeheads with feed to strengthen the propaganda efforts to eliminate the doubts of the farmers. (4) To solve the problems of farming enterprises, make technology services to the industry. (5) Formulate relevant policies, strictly prohibit the direct feeding of forage fish, enforce the standard of tailwater discharge, and promote the ecological culture of snakehead. (6) Give appropriate financial subsidies from the government's perspective to reduce the cost of compound feed, and ensure the sustainable development of snakehead culture through policy support.

In conclusion, feeding snakeheads with feed can enhance the survival rates, has a lower bait coefficient, higher nutritional value, safer and more hygienic sources. It also can significantly reduce the occurrence of disease in cultured snakeheads, and effectively solve the pollution of cultured tailwater discharge. Therefore, we should focus on the problems faced by snakeheads with feed industry, promote the research and development. The promotion and

application of compound feed, replacement of forage fish with feed, are promoting the sustainable green development of snakehead aquaculture industry in Shandong province.

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IRB approval

Approval was obtained from Institutional Review Board of our university for this study.

Ethical statement

These investigations were approved by the Ethics Committee for Animal Care and Experiments at Jinan Vocational College.

Statement of conflict of interest

The authors have declared no conflict of interest.

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