Alternative Feeding Strategies and Feed Ingredients for Snakehead Farming in Cambodia and Vietnam

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Prior to 2006, the predominant method for culturing snakehead in Vietnam and Cambodia was to collect wild juveniles from natural sources like the Mekong River and Tonle Sap. Particularly in Cambodia, aquaculture farmers, who were also fishermen, would collect their own fingerling snakehead. They would then also collect "small fish" (also known as low-value fish or trash fish) from natural sources, chop them up and feed them to the snakehead in culture. A conflict existed between users of these fish: the aquaculture/fishing people and the remainder of the Cambodian population who rely on small fish (Fig. 1) for a variety of products, including fish sauce and prahok, that provide protein to the Cambodian people throughout the year. As a result, and to protect the nutrition of the Cambodian people, aquaculture of snakehead was banned in the country in 2004.

FIGURE 1. *Cambodians sorting small fish to use in products for human nutrition.*

SNAKEHEAD FARMERS COLLECT "SMALL FISH" FROM NATURAL SOURCES, CHOP THEM UP AND FEED THEM TO THE SNAKEHEAD. A CONFLICT EXISTED BETWEEN USERS OF THESE FISH: THE AQUACULTURE/FISHING PEOPLE AND THE REMAINDER OF THE POPULATION WHO RELY ON SMALL FISH TO PROVIDE PROTEIN TO THE CAMBODIAN PEOPLE THROUGHOUT THE YEAR.

Snakehead culture continued in Vietnam. Wild fingerlings were collected from the Mekong River, but anecdotal reports indicated that wild fish could never be induced to eat pelleted feed. Farmers continued to rely on chopped-up small fish that were also collected from the wild. Beginning in the late 1990s, efforts were made to develop hatcheries to domesticate snakehead for a steady supply of fingerlings that did not rely on natural sources. Although common breeding techniques from around the world could be used to induce spawning, larval rearing practices relied on use of live feed (the cladoceran *Moina* spp.) followed by chopped small fish as a weaning diet. Grow-out production continued to rely on chopped small fish. Concerns mounted that harvesting small fish from the Mekong River for an expanding snakehead aquaculture industry would eventually lead to detrimental impacts on those populations of small fish.

In 2007, the U.S. Agency for International Development-funded Aquafish Collaborative Research Support Program, later re-named the AquaFish Innovation Lab, funded a project to address the sustainability of snakehead culture in Vietnam and Cambodia. A major aspect of the project was the development of diets and feeding strategies that would obviate the need for small fish usage in snakehead culture. This occurred in a series of steps, as follows.

Assessment of Species Composition and Nutritional Value of Small Fish Used in Snakehead Culture in Cambodia in Vietnam

In Cambodia, three types of feed sources were traditionally supplied to snakehead fish farms. Home-made, freshwater trash fish feed was the most common feed, and marine trash fish, crabs and snails were also used (Hap *et al*. 2010). Around 200 species of trash fish were used for snakehead culture, including small life stages (larvae and fingerling) of economically important species that contribute about 10 percent of the total collection of trash fish. In Vietnam, sampling of small fish from fish distribution sites in the Mekong Delta indicated that freshwater small fish used in snakehead culture came from 33 species, of which 12 were actually the juvenile stages of commercially important species (Hien *et al*. 2015a). Because the freshwater small fish were obtained locally, they were reasonably fresh, but marine fish, collected from farther away (and not delineated by species), showed greater degrees of deterioration in nutritional quality. This step reinforced the idea that pelleted diets must be developed to eliminate the wild capture of small fish.

Development of Weaning Strategies for Snakehead

Based on anecdotal information that snakehead would not accept pelleted diets if they were introduced to them after a certain life stage, scientists at Can Tho University (CTU) developed weaning protocols for snakehead (Hien *et al*. 2017). The snakehead murrel *Channa*

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striata can be weaned beginning at 17 days after hatch (DAH) and can fully accept pelleted diets 10 days later. However, the giant snakehead *Channa micropeltes* must begin weaning later at 40 DAH and the weaning period to full acceptance of pellet diets requires 30 days. Successful completion of this step allowed for the testing of pellet diets using standard fish nutrition experimental techniques.

Development of Pelleted Diets for Snakehead in Vietnam

Based on previous work at the University of Rhode Island (URI) on replacement of fishmeal in diets for summer flounder (Enterria *et al*. 2011, Lightbourne 2011), experiments were designed and conducted at CTU to determine the maximum levels of fishmeal that could be replaced by plant proteins with and without the addition of supplemental amino acids, taurine and phytase (Hien *et al*. 2015b) in diets for *C. striata*. These experiments showed that 40 percent of fishmeal could be replaced by soybean meal, provided certain amino acids and phytase were added. Based on these laboratory experiments, pond trials were then conducted at CTU to compare the new pelleted diet against the traditional diet of chopped small fish in terms of fish survival and growth, and product quality determined in a sensory evaluation. Further pond trials were conducted on commercial farms to evaluate the commercial feasibility of using pelleted diets.

FIGURE 2. *A Vietnamese farmer feeding snakehead with the newly developed pellet diet.*

FIGURE 3. *Training for women on seed production, grow-out and disease prevention and treatment of snakehead in the provinces of An Giang, Dong Thap and Tra Vinh, Vietnam in April, 2017.*

Replacing small-sized fish for snakehead aquaculture with pelleted feed would reduce the pressure on stocks of small fish. There are strong economic incentives for farms to use pelleted feed. Over time, pelleted feed became less expensive and more cost effective for medium- and low-productivity farms. NPVs were more sensitive to reduction in the cost of pelleted feed than to increased cost of small fish or the cost of capital.

All findings were extremely positive (Hien *et al*. 2016a). There were no significant differences between fish raised using pelleted diets versus those fed chopped small fish in the CTU pond trials. Furthermore, economic analysis indicated that profits were greater using pelleted diets on the commercial farms tested.

The CTU diet formulation was shared with feed mills in the Mekong Delta by CTU researchers, along with further outreach and demonstration projects for farmers in An Giang and Dong Thap provinces. This led to widespread adoption of pelleted diets by snakehead farmers in Vietnam (Fig. 2). In recent years, special efforts have been made to educate women to become snakehead farmers (Fig. 3).

Economic Analysis of Alternative Snakehead Feed

Replacing small-sized fish for snakehead aquaculture with pelleted feed would reduce the pressure on stocks of small fish. Grimm-Greenblatt *et al*. (2015) studied the economics of this replacement strategy for snakehead culture in Vietnam. Economic engineering methods were used to assess the effects of pelleted feed for low-, medium- and high-productivity scenarios. The study compared net present values (NPV), internal rates of return (IRR) and differences in NPV between farms using pelleted feed and those using small fish. It also included sensitivity analyses that related NPV and IRR to increased snakehead prices. Results demonstrated strong economic incentives for farms to use pelleted feed. Over time, pelleted feed became less expensive and more cost effective for medium- and low-productivity farms. NPVs were more sensitive to reduction in the cost of pelleted feed than to increased cost of small fish or the cost of capital.

Investigation of Soy Protein Concentrate and Immunostimulants

Again based on previous work with summer flounder at URI (Ward 2014, Ward *et al*. 2016), we investigated whether soy protein concentrate (SPC) might be a better component than soybean meal in pelleted diets for snakehead. SPC has a higher protein level than soybean meal and few to none of the anti-nutritional compounds found in soybean meal. Flounder work at URI had indicated that certain oligosaccharide compounds (stachyose and raffinose) in soybean meal, but missing from SPC, serve an immunostimulatory function.

Experiments at CTU indicated that SPC could not be added to snakehead diets at levels greater than 40 percent, i.e., similar to soybean meal (Hien *et al*. 2016b). In addition, SPC is considerably

more expensive than soybean meal and is more difficult to obtain in Vietnam. Stachyose and raffinose are prohibitively expensive in Vietnam, even for small-scale experiments, so a commercial immunostimulant (containing mannan oligosaccharide) was tested as a dietary additive.

After an eight-week feeding trial, fish fed diets containing the immunostimulant showed increased immune responses for factors such as immunoglobulins and lysozymes, but diet did not affect fish survival in a subsequent 15-d bacterial challenge with *Aeromonas hydrophila*, a known pathogen of snakehead. These experiments resulted in a decision not to focus on SPC in snakehead diet development in Vietnam or Cambodia.

Investigation of Vitamin C Requirements of Snakehead in Vietnam

As pelleted feed usage in Vietnam became widespread, some farmers reported abnormalities in the *C. striata* that they were producing, particularly lordosis and scoliosis of the vertebral column (Hien *et al*. 2016a). Such abnormalities are widely known in aquaculture worldwide and are caused by inadequate levels of dietary ascorbic acid (vitamin C).

In the final phase of snakehead diet investigations in Vietnam, we investigated ascorbic acid requirements of *C. striata*. Two experiments were conducted, one each in hatchery and grow-out phases (Hien *et al*. submitted) (Fig. 4). In the hatchery phase, maximal growth was observed at 500 mg/kg vitamin C in the diet, although differences were not significantly different at 250, 500, 1000 and 2000 mg/kg.

In the bacterial challenge following the feeding trial, mortality was significantly reduced from about 60 percent (0 mg/kg and 2000 mg/kg) to about 20 percent (500 mg/kg and 1000 mg/kg). Results of the grow-out experiment at a commercial facility confirmed that vitamin C should be added to snakehead diets in the 250-500 mg/kg range, substantially higher than levels previously used.

FIGURE 4. *Snakehead hapas in pond vitamin C trial in 2017 in Vietnam.*

FIGURE 5. *The Baty Hatchery Center, Prey Veng province, Cambodia.*

As part of a technology transfer program between Vietnam and Cambodia, fish of Vietnamese origin grew markedly and significantly better in hatchery and grow-out compared to all those of Cambodian origin. This suggests that the roughly two decades of fish breeding for snakehead domestication in Vietnam have resulted in fish that grow better under controlled aquaculture conditions.

Transfer of Technology to Cambodia

Because snakehead culture was banned in Cambodia, diet and feeding strategy technology was transferred from CTU in Vietnam to the Inland Fishery Research and Development Institute (IFReDI), a government agency in Cambodia. First, CTU researchers transferred technology for controlled breeding and larval rearing to personnel at the IFReDI hatchery at Baty Hatchery Center, Prey Veng province, Cambodia (Fig. 5). In particular, IFReDI scientists wanted to use snakehead of Cambodian origin in their research program, so a major focus was on the use of Vietnamese diets and protocols developed for domesticated fish with wild Cambodian fish. Once IFReDI researchers were able to produce sufficient numbers of offspring from Cambodian fish, they compared hatchery (weaning) success of wild Cambodian fish with domesticated Vietnamese fish and followed that with a comparison of grow-out success (Nen *et al*., submitted).

In the hatchery phase, fish of Vietnamese origin grew markedly and significantly better (10.9 g/fish) compared to all those of Cambodian origin: Tonle Sap (4.6 g/fish); Mekong (3.2 g/fish); and F1 from IFReDI broodstock (4.9 g/fish). In the grow-out phase, the greater weight gain of Vietnamese-origin fish (324 g/fish) was continued compared to Cambodian-origin fish: Tonle Sap (148 g/fish), Mekong (133 g/fish), and F1 (147 g/fish). This suggests that the roughly two decades of fish breeding for snakehead domestication in Vietnam have resulted in fish that grow better under controlled aquaculture conditions.

Finally, a five-month feeding trial to confirm the Vietnamese vitamin C results was conducted in experimental ponds at IFReDI. Growth performance (final weight, daily weight gain and yield) of fish in the experimental diet plus 500 mg/kg vitamin C treatment was significantly greater than that in the commercial feed treatment.

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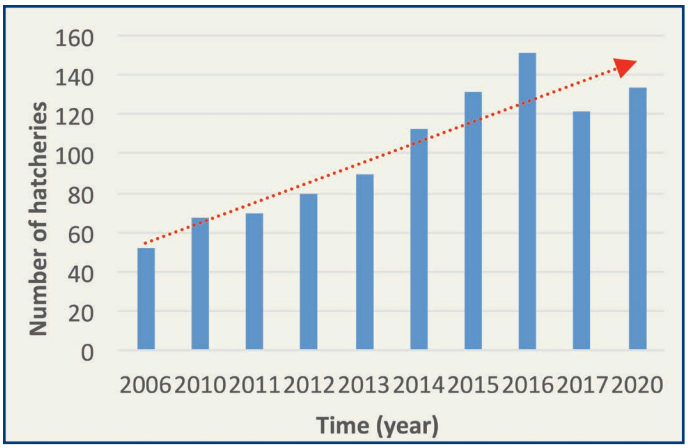

FIGURE 6. *Snakehead fish hatchery development in Vietnam. The number for 2020 is an estimate.*

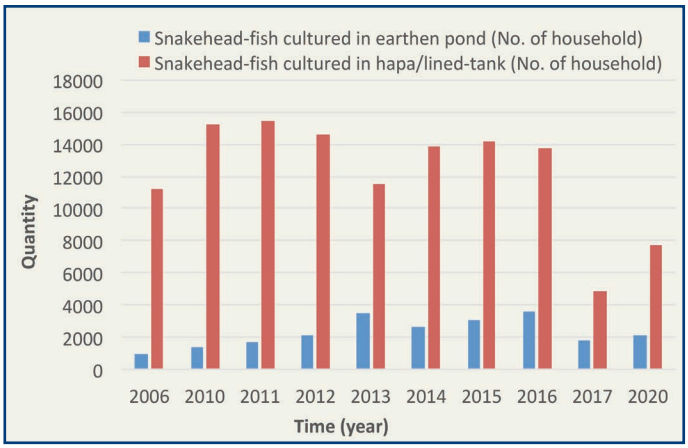

FIGURE 7. *Number of Vietnamese households culturing snakehead in earthen ponds or in hapas or lined-tanks. The 2020 numbers are estimates.*

Furthermore, spinal abnormality rate of fish in the experimental diet plus 500 mg/kg vitamin C treatment was significantly lower than that in the commercial feed treatment, but survival, cannibalism, and FCR were not significantly different.

Outcomes

Based largely on the results of our AquaFish project, in June 2016, the Government of Cambodia lifted the decade-old ban on snakehead fish farming following a request from the Ministry of Agriculture to allow farmers to fish. The statement said the decision to legalize snakehead farming again would be accompanied by forthcoming conditions and advice for farmers and it would help farmers sustainably manage and maintain their farms and keep fish stocks healthy.

Currently Cambodia has identified aquaculture as one among the most important three pillars of the country's fisheries development. The government's Strategic Planning Framework for Fisheries for 2010 to 2019 considers expanding the farming of fish and other aquatic animals as "essential" given the limited capacity of natural resources to sustain the country's growing population. In general, to support the growth of small-, medium- and large-scale freshwater aquaculture, government spending on aquaculture has been budgeted at more than US$16 million under the 10-year framework. Recently, aquaculture extension is one of the national policies under the Strategic Plan Framework for the fisheries sector.

Due to advances in controlled reproduction and weaning techniques, the number of hatcheries in Vietnam has increased considerably (Fig. 6) from slightly more than 50 in 2006, when this project began, to about 150 in 2016. Although about 30 hatcheries stopped operating between 2016 and 2017, the quantity of fingerlings increased from 148 to 170 million from 2016 to 2017. The reasons that the number of hatcheries decreased are: 1) small-scale hatcheries shifted to produce other species of fingerlings or closed due to competition with large hatcheries, 2) large-scale hatcheries provided the majority of fingerlings and their cost per fingerling is cheaper and 3) the cost of snakehead fish production decreased in 2017 so that some hatcheries also temporarily stopped produce fingerlings. Although the number of broodstock is not increasing markedly, the production of fingerlings is, indicating that hatchery efficiency is improving. The number of Vietnamese households devoted to each type of snakehead production has not markedly increased over the last few years (Fig. 7).

Regarding environmental improvement, Hien *et al*. (2016a) showed that better pond water quality results when pelleted diets are used, compared to trash fish, which likely contributes to the improved profits seen with pelleted feed. Perhaps more important, usage of small fish from the wild for snakehead culture in Vietnam has been reduced (Fig. 8) and use of small freshwater fish in particular has been reduced. As small-fish usage has decreased, the number of commercial feed mills making snakehead feed has increased from five in 2010 to more than 20 today and total commercial feed production has approximately doubled.

Finally, and perhaps most important, the snakehead ban in Cambodia was lifted in June 2016. Nonetheless, some research and considerable outreach must be done in Cambodia to implement a viable snakehead industry.

Notes

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References

Enterria, A., M. Slocum, D.A. Bengtson, P.D. Karayannakidis and C.M. Lee. 2011. Partial replacement of fish meal with plant protein sources singly and in combination in diets for summer flounder (*Paralichthys dentatus*). Journal of the World Aquaculture Society 42:753-765.

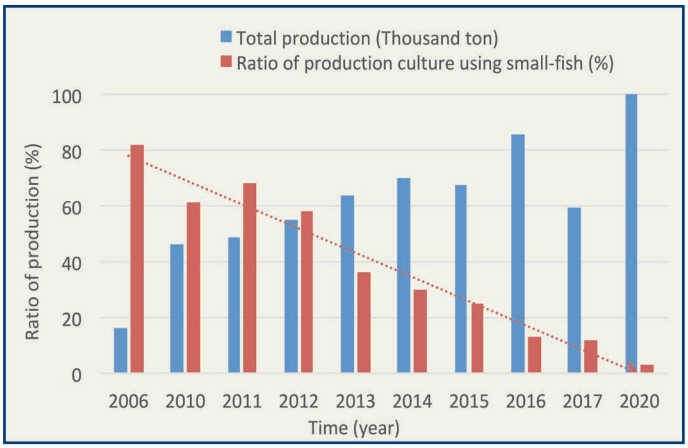

FIGURE 8. *Reduction of snakehead production using small fish as feed over time in Vietnam.*

Grimm-Greenblatt, J., R. Pomeroy, B. Bravo-Ureta, Le Xuan Sinh, Huynh Van Hien and T. Getchis. 2015. Economic analysis of alternative snakehead *Channa striata* feed. Aquaculture Economics and Management 19:192-209.

Hap, N. and R. Pomeroy. 2010. Competition and Impacts between Uses of Low Value Fish for Aquaculture Feed versus Uses for Human Food in the Lower Mekong Basin of Cambodia. AquaFish CRSP Report, University of Connecticut-Avery Point.

Hien, T.T.T., T.T. Be, C.M. Lee and D.A. Bengtson. 2015b. Development of formulated diets for snakehead (*Channa striata* and *Channa micropeltes*): can phytase and taurine supplementation increase use of soybean meal to replace fish meal? Aquaculture 448:334-340.

Hien, T.T.T., T.D. Dinh, T.M. Phu and D.A. Bengtson. 2015a. Assessment of the trash-fish diet for snakehead aquaculture in Vietnam: species composition and chemical characterization. Asian Fisheries Science 28:165-173.

Hien, T.T.T., P.M. Duc, T.L.C. Tu,T.M. Phu, D.T.M. Thy and D.A. Bengtson. 2016c. Growth performance and immune response of snakehead (*Channa striata*) fed soy diets with supplementation of mannan oligosaccharide. Asian Fisheries Science 28:67-81.

Hien, T.T.T., N.H.D. Trung, B.M. Tam, V.M.Q. Chau, N.H. Huy, C.M. Lee and D.A. Bengtson. 2016a. Replacing freshwater small-size fish by formulated feed in snakehead (Channastriata) aquaculture: experimental and commercial-scale pond trials, with economic analysis. Aquaculture Reports 4:42-47.

Hien, T.T.T., T. M. Phu, T.L.C. Tu, N.V. Tien, P.M. Duc and D.A. Bengtson. 2016b. Effects of replacing fishmeal with soya protein concentrate on growth, feed efficiency and digestibility in diets for snakehead, *Channa striata*. Aquaculture Research 48:3174-3181.

Hien, T.T.T., B.M Tam, T.L.C. Tu and D.A. Bengtson. 2017. Weaning methods using formulated feeds for snakehead (*Channa striata* and *Channa micropeltes*) larvae. Aquaculture Research 48:4774-4782.

Lightbourne, C. 2011. Effects of soybean meal replacement with added taurine in fish meal diets for summer flounder (*Paralichthys dentatus*). M.S. Thesis, University of Rhode Island, Kingston, RI, USA.

Nen, P., P. Chheng, N. So, H. Egna and D.A. Bengtson. In preparation. Performance of domesticated (Vietnamese) vs. non-domesticated (Cambodian) snakehead, *Channa striata* (Bloch 1793) with regard to weaning onto pellet feed and growout. Asian Fisheries Science.

Nen, P., N. So, S.H. Pheng and R. Pomeroy. 2017. Weaning and Grow-out of Striped Snakehead Channastriata, Sustainable Snakehead Aquaculture Development in the Lower Mekong River Basin of Cambodia. 2016 AquaFish Technical Meeting. Asian-Pacific Aquaculture Conference Surabaya, Indonesia 27-28 April 2016

Ward, D. 2014. Nutritional and immunological evaluation of soy-based diets for summer flounder (*Paralichthys dentatus*) aquaculture. Ph.D. Dissertation, University of Rhode Island, Kingston, RI, USA.

Ward, D., D.A. Bengtson, C.M. Lee and M. Gomez-Chiarri. 2016. Incorporation of soybean products in summer flounder (*Paralichthys dentatus*) feeds: effects on growth and survival to bacterial challenge. Aquaculture 452:395-401.