DEVELOPMENT OF INNOVATIVE FEED TECHNOLOGIES

and Strategies for Small-Holder Aquaculture Operations

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Reducing costs associated with feeds is a chief focus area for research supported by the AquaFish Innovation Lab. Since feed costs amount to the majority of operation costs in smallholder aquaculture, reducing these costs will increase income, particularly for those that are especially vulnerable to changes in operating costs. Although quality feeds are critical to optimal fish growth and production, they are not readily available in many areas, and the high costs may limit economic success for rural fish farmers. Using alternative feed sources and feeding strategies can decrease production costs, reduce reliance on expensive feeds, and increase overall fish yield.

Alternative Feed Sources

Invertebrates

AquaFish researchers at **Sokoine University of Agriculture in Morogoro, Tanzania**, investigated invertebrates — housefly larvae and earthworms — as affordable and locally grown alternative protein for feeds that both have short life-cycles and high fecundity.

Results showed that a 35% inclusion of either earthworms or housefly larvae as protein sources in tilapia feed resulted in the highest production and the most cost-effective composition of all the diets studied.

This study identified alternative, high-protein feed ingredients and also taught farmers to produce these invertebrates themselves using locally available, low-cost substrates.

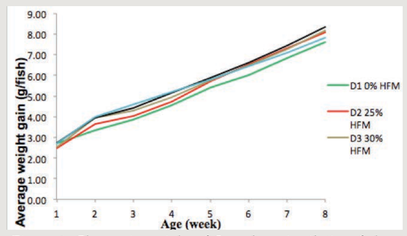

Figure 1: Change in weight of *Oreochromis niloticus* fed housefly larvae meal-based diets.

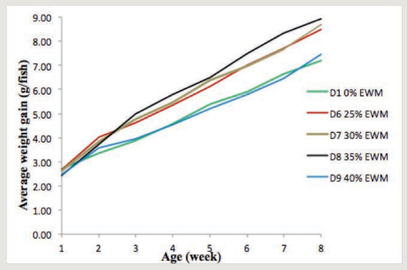

Figure 2: Change in weight of *O. niloticus* fed earthworm meal-based diets.

Figures from Chenyambuga et al 2016. *Evaluation of Invertebrates as Protein Sources in Nile Tilapia* (Oreochromis niloticus) *diets.* AquaFish Innovation Lab, Corvallis, OR, 97331.

Plant-Based

AquaFish researchers at **Can Tho University, Vietnam, and the University of Rhode Island** are working on developing cost-effective alternative feeds for small-scale snakehead farming with soybean, rice bran, and cassava as a replacement for fishmeal (FM). Snakehead culture is growing significantly throughout the Mekong Delta, yet traditional feeds composed of wild-caught, low-value fish are expensive and not sustainable.

Researchers tested five feeds, each consisting of varying amounts of fishmeal and soy protein concentrate (SPC). Results reveal that the snakehead fed a feed comprised of 40% SPC (60% FM) performed on par with those fed 100% FM.

Treatment	FI (%/fish/day)	FCR	PER (%)	NPU (%)
100% FM	3.36±0.13^{a}	0.84±0.10c	2.76±0.34^{a}	46.9±4.25^{a}
40% SPC	3.12±0.32^{a}	0.83±0.05^{c}	3.17±0.82^{a}	50.2±1.70^{a}
60% SPC	1.96±0.14^{b}	1.20±0.03^{b}	1.93±0.05^{b}	21.3±1.78^{b}
80% SPC	1.84±0.10^{b}	1.19±0.03^{b}	1.89±0.05^{b}	19.4±1.17^{b}
100% SPC	1.31±0.08^{c}	1.70±0.09^{a}	1.32±0.07^{b}	12.6±2.83^{c}

Table 1: Feed intake (FI), feed conversion ratio (FCR), protein efficacy ratio (PER), and net protein utilization (NPU) of fish fed diets in which varying levels of fish meal (FM) were replaced by soy protein concentrate (SPC). Values (mean ± SD) in a column followed by the same superscript letter are not significantly different.

Table from Hien et al 2016. *Use of soy products in snakehead diet.* AquaFish Innovation Lab, Corvallis, OR, 97331.

These fish had significantly better growth and survival rates compared to the other three treatments, as well as significantly higher feed intakes, and better feed conversion ratios, protein efficiency ratios, and net protein utilization.

Feeding Strategies

Feed Reduction

AquaFish researchers in **Bangladesh** applied lessons learned from AquaFish feeds research in the Philippines that showed that alternate-day feeding at full ration was as effective at producing tilapia of similar yield as fish fed at full daily ration.

In a polyculture study of major Indian carp (rohu) with tilapia, fish were fed at a 50% reduction in daily feed along with weekly pond fertilization.

Parameter	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Rohu	0	25 (0.625/ m^2)	0	25 (0.625/ m^2)
Tilapia	500 (5.0/ m^2)	500 (5.0/ m^2)	500 (5.0/ m^2)	500 (5.0/ m^2)
Fertilization	0	0	4:1 (N: P)	4:1 (N: P)
Feeding	100% Satiation	100% Satiation	50% Satiation	50% Satiation
Replicates (*n*)	4	4	4	4

Table 2: Treatment scenarios for each freshwater pond of 100m^2 at BAU's Fisheries Field Lab.

Table from Borski 2015. Quarterly Report. AquaFish Innovation Lab, Corvallis, OR, 97331.

A 50% reduction in daily feed ration in polyculture systems of tilapia and indigenous carp did not negatively affect overall production and resulted in significant cost savings to farmers, increased access to multiple fish species, and minimized nutrient inputs in the environment.

Periphyton Enhancement

Adding substrates such as bamboo to carp ponds can increase carp production by facilitating growth of periphyton, which serves as food for fish. AquaFish researchers at the **Agriculture and Forestry University, Nepal,** conducted trials to determine the best combination of carp, small indigenous species (SIS), and periphyton at 100% and 50% feeding to maximize net fish yield.

Total fish production was 51.7% higher in carp+SIS+periphyton with 50% feeding than in carp polyculture with 100% feeding

Variable	Chitwan		Nawalparasi	
	Carp	Carp+SIS+substrate	Carp	Carp+SIS+substrate
carp production (kg/100 m^2)	26.8	35.3	33.1	37.6
SIS production (kg/100 m^2)	0.10	1.06	0.13	0.48
Total production (kg/100 m^2)	26.9	36.4	33.2	38.1
Extrapolated NFY (t/ha/yr)	4.1	5.5	5.0	5.8
AFCR	4.6	2.3	4.0	1.9

Table 3: Fish (carp and SIS) production in two treatments in Chitwan and Nawalparasi districts, Nepal.

Table from Jha et al 2016. *Production of Periphyton to Enhance Yield in Polyculture Ponds with Carps and Small Indigenous Species.* AquaFish Innovation Lab, Corvallis, OR, 97331.

Nutrient Uptake

Digestibility

AquaFish researchers at the **University of Eldoret, Kenya,** developed mechanisms for fish feed formulation and processing to improve growth and production of tilapia in Western Kenya. This work aimed to positively influence pond water quality as a lot of nutrients in feeds are lost during preparation, manufacturing, and storage. Many available commercial feeds also have anti-nutritional components and variable degrees of digestibility, compromising fish growth and survival.

This study formulated diets using locally available ingredients balanced with essential amino acids to enhance the physical quality and nutritive value for *Oreochromis niloticus*.

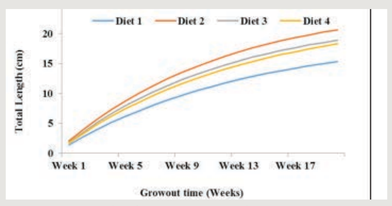

Figure 3: Growth of mono-sex *O. niloticus* over 105 days on the four test diets.

Ingredient	Diet 1	Diet 2	Diet 3
Wheat bran	48.0	48.0	48.0
Caridina niloticus	30.0	30.0	30.0
Cotton seed meal	18.0	18.0	18.0
Fish oil	2.0	2.0	2.0
Trace mineral	1.0	1.0	1.0
Lysine%	1.96% + Supplement 2.7 g kg^{-1}	1.96% + Supplement 2.7 g kg^{-1}	No supplement
Methionine%	0.95% + Supplement 5.1 g kg^{-1}	No supplement	No supplement

Table 4: Ingredients and chemical composition of experimental diets used for feeding *O. niloticus* fingerlings.

(Graphics from Manyala et al 2016. *Formulation and Manufacture of Practical Feeds for Western Kenya.* AquaFish Innovation Lab, Corvallis, OR, 97331.)

Gut Flora Analysis

AquaFish researchers at **Bangladesh Agricultural University** assessed how pulsed feeding affects growth performance, gastrointestinal nutrient absorption efficiency, and establishment of beneficial gut flora for tilapia pond culture.

The project aimed to characterize changes in gut microbial communities in response to different feeding strategies and to establish whether these changes are associated with nutrient availability and uptake efficiency (according to amino acid and lipid transporters in the intestine).

Researchers accomplished this by evaluating the microbiome of tilapia feces from tilapia grown in ponds under different feeding regimes including: fertilized and fed every day; unfertilized and fed every every day; fed on alternate days; fed every third day; and not fed at all.

The results suggest that a combination of alternate-day feeding and fertilization increases gut microbiota diversity and regulates nutrient uptake, which may improve tilapia growout production.

The microbiome revealed 20 unique species of bacteria in this treatment. The predominant bacteria found were:

- *Cetobacteriam somerae* (common gut colonizer of Nile tilapia)
- Bacteria from the family Peptostreptococcaceae
- *Clostridium perfringens*

All photos and graphics provided by the AquaFish Innovation Lab.

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