Improving Feed Quality, Availability, and Cost with Alternative Feeds and Feeding Regimes for Smallholder Aquaculture Operations

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Introduction

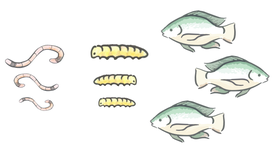
Aquaculture growth for smallholder farms is often limited by a lack of access to affordable, high-quality feed sources. Furthermore, feed costs constitute the majority of production costs which are estimated to be between 60-80% for tilapia, one of the most widely cultured species in the world. Research supported by the AquaFish Innovation Lab in Africa and Asia is **focusing on reducing operational costs and negative environmental impacts by developing alternative feed types and feeding regimes** while maintaining high yields.

More specifically, research involves investigating affordable and locally sourced feeds and **examining how pulsed feeding strategies affect fish gut biomes** to improve nutrient uptake efficiency from feeds. In doing so, AquaFish researchers are improving feed quality and availability and reducing reliance on expensive feeds, which will increase productivity and sustainability of small-scale aquaculture operations in communities across the globe.

Feed Ingredients

AquaFish researchers have tested alternative feed ingredients that are locally sourced and more affordable than their expensive resource intensive fishmeal counterparts.

At **Sokoine University of Agriculture in Morogoro, Tanzania**, AquaFish researchers investigated invertebrates – housefly larvae and earthworms – for use in fish feeds as they both have short life-cycles and high fecundity. Results produced a cost-effective and protein-efficient composition for tilapia production.



The chemical composition of maggots (*Musca domestica*), earthworms (*Lumbricus terrestris)*, and fish meal were determined for crude protein, fat, crude fiber, and ash. Based on results, nine feed formulations were developed using mixtures of fish meal, maggot meal (HM), earthworm meal (EWM), and cotton seed cake. A feeding experiment was conducted to evaluate the growth performance, feed utilization, and cost effectiveness of the nine feeds on Nile tilapia. Growth,feed utilization, and cost was most optimal in fish fed diets with 35% HM and EWM and 5% fish meal or plant protein.

At **CanTho University, in Vietnam** and the **University of Rhode Island**, AquaFish researchers developed alternative feeds for small-scale snakehead farming with soybean, rice bran, and cassava, to reduce fishmeal content in commercial diets.

Feed Strategies

Groundbreaking AquaFish feeds research at **Central Luzon State University** in the **Philippines** found that feeding tilapia on alternate days was effective at producing tilapia at similar yields as if fed at a full daily ration.

These findings have served as the baseline for other AquaFish studies that have assessed the outcomes of alternate-day feeding for other fish species as well as polyculture systems. If alternate-day feeding can produce equivalent fish production rates, while also cutting feed costs in half and reducing nutrient inputs to the environment, then it is a worthwhile strategy to promote for aquaculture.

Impacts on nutrient availability and beneficial gut flora of fish

Background

- Improving the understanding of how finfish acquire and utilize nutrient inputs is essential to future improvements in aquaculture production efficiency.
- Feed ingredients and feeding strategies can influence the diversity and abundance of intestinal microbiota in both humans and fish.
- Reduced feeding can potentially enhance nutrient uptake efficiency or promote foraging on in-pond primary production, diversifying the fish's diet and enhancing nutrient recycling in ponds.

Research in the Philippines demonstrated that equivalent production yields can be achieved with much less feed (50% reduction) through the implementation of pulsed feeding strategies. Follow-up experiments at **Bangladesh Agricultural University** and **North Carolina State University** examined how alternate-day feeding strategies may enhance nutrient absorption by measuring nutrient transporter abundance and gut microbial diversity in response to different feeding regimes.

Feed variations were tested according to their impact on the:

- Growth performance,
- Gastrointestinal nutrient absorption efficiency, and
- Establishment of beneficial gut flora for tilapia pond culture.

Results

Metagenomic analyses identified 145 different families of prokaryotic (all bacteria) and 132 eukaryotic organisms in the fecal material of tilapia (Figures 1and 2). The highest diversity of eukaryotes was found in **fish fed every other day with pond fertilization.**

There were no significant differences in gene expression of these nutrient transporters in any treatment that incorporated both feeding and pond fertilization. Expression of the transporters was higher in fish that were not fed and grown in fertilized ponds and lower in fish that were fed daily without pond fertilization. Fish fed on alternate days had more moderate expression levels of certain transporters which may allow for more balanced and efficient nutrient uptake.

Together, these studies along with those in the Philippines indicate **feeding Nile tilapia on alternate days along with weekly pond fertilization has no negative effects on growth, survivability, or production** compared to daily feeding regimes, and additionally produces the greatest net return on investments.

This work also suggests for the first time that **combined feeding and fertilization produces the greatest biodiversity of microbiomes in the intestine** which could contribute to enhanced feed efficiency and overall health of tilapia, particularly those subjected to more moderate feeding strategies. This work lays the framework for development of probiotic supplements that can be incorporated into diet formulations for improving growth and nutrient absorption.

Treatment / Factors	Daily feeding with 4:1 (N:P) weekly	Feeding every other day 4:1 (N:P) weekly	Feeding every 3rd day 4:1 (N:P) weekly	No feeding 4:1 (N:P) weekly	Daily feeding No fertilization
Stocking Density	5 fish/ m^2	5 fish/ m^2	5 fish/ m^2	5 fish/ m^2	5 fish/ m^2
Initial Weight (g)	3.55±0.90^a	3.55±0.90^a	3.55±0.90^a	3.55±0.90^a	3.55±0.90^a
Final Weight (g)	127.63±2.75^a	120.17±5.44^a	85.10±11.13^b	43.15±4.28^c	129.53±8.59^a
Weight Gain (g)	124.08±2.75^a	116.62±5.44^a	81.55±11.13^b	39.60±4.28^c	125.98±8.59^a
SGR (%/day)	3.14±0.02^a	3.09±0.04^a	2.78±0.12^b	2.19±0.09^c	3.15±0.06^a
FCR	1.64±0.10^c	0.93±0.09^b	0.68±0.15^a	--	1.61±0.10^c
Survival Rate (%)	93.44±6.26^a	91.66±8.00^a	90.70±9.74^{ab}	76.79±2.68^b	97.71±2.11^a
Production (kg/pond)	92.98±10.29^{ab}	86.40±9.33^b	58.93±7.17^c	27.50±4.57^d	102.63±10.66^a
Net Production (kg/ha)	6091.42±354.52^a	5658.26±527.83^a	4086.39±640.07^b	1796.04±233.89^c	6392.81±461.41^a
Total Production (kg/ha)	6282.09±354.52^a	5837.84±527.83^a	4179.08±640.07^b	1950.35±233.89^c	6578.53±461.41^a

Table 3: Growth factors according to five different treatments. Values with different leters are significantly differrent (P<0.05).[1]

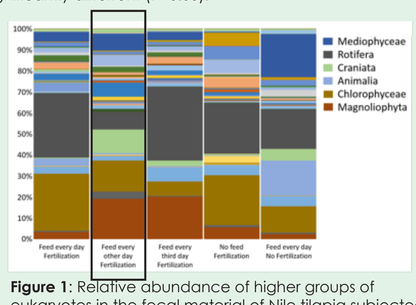


Figure 1: Relative abundance of higher groups of eukaryotes in the fecal material of Nile tilapia subjected to varying pulsed-feeding regimes.[1,2,3]

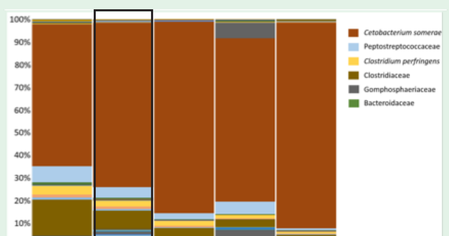


Figure 2: Relative abundance of bacteria in the fecal material of Nile tilapia subjected to varying pulsed-feeding regimes at the level of Family/Species.[1,2,3]

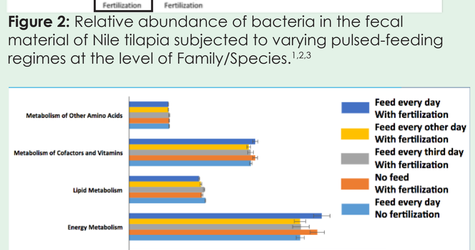


Figure 3: Predicted metabolic function of gut flora that may affect metabolism and nutrition in fish.[3]

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