Farm-Generated Feed: Fish Feed Production

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[Editor's Note: Keith has been practicing sustainable farming at the Aloha House Orphanage in Puerto Princesa for many years in order to produce nutritionally dense, farm-derived food that is consumed both at the orphanage and by local consumers. I had the privilege of visiting Keith and his family last March at the Aloha House, where the ECHO Asia/Aloha House Sustainable Agriculture Workshop was held. I was impressed by what they are able to achieve with very few off-farm inputs in a small amount of land area. In this article, Keith will share some of the basics for creating farm-generated fish feed.]

Farm-generated fertility makes agriculture more sustainable. Crop residues and manures are part of the nutrient cycle and can lower input costs through the use of thermophilic composting, vermiculture, bokashi production, or green manures. Farm-generated feeds can also reduce expenses, if farmers manage and utilize the resources already available to them. For, example, farmers might develop pasture using planned grazing for cattle; make hog feed from crop residue and by-products (such as whey and skim milk); cultivate legume shrubs for cut-and-carry operations for goats; and grow floating ferns and other water crops for fish and poultry.

As densities of livestock increase, the industrious farmer finds ways and means to increase his farm nutrient stream for the benefit of his system. This article will examine the methods and techniques necessary for the smallholder farmer to succeed with farm-derived fish feeds. A farmer should first fully exploit his extensive (and more passive) existing systems, and then consider intensifying his overall operation (Figure 1).

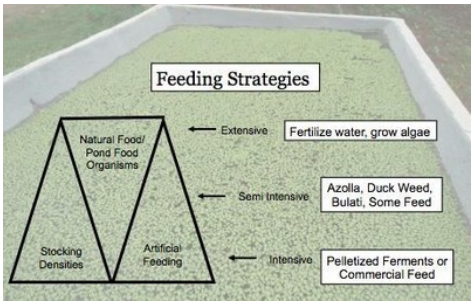

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Figure 1. Feeding strategies for fisn, ranging from extensive to intensive.

Important: Note that many journals, papers, and guides caution against the tendency to abandon established methods of feed production for a more intensive system without first assessing and then establishing new technologies with a transition period that is well-planned, capitalized and realistic.

Overview of the Aloha System

Planning includes securing both on-farm and off-farm feed sources, in case of contingencies. "Most farmers do not maintain all the ingredients needed to prepare a complete feed on-site or the equipment to blend and pellet it. They must, therefore, have guaranteed primary and alternative market sources at all times, which is not a simple management activity," (Skillicorn et al., 1993). Our experience is with the tilapia GIFT variety, Improved Excel variety, and red tilapia from the Bureau of Fisheries and Aquatic Resources in the Philippines, as well as with Japanese koi obtained from commercial breeders in the Philippines (Figure 2). In our closed-loop recirculating aquaponic systems, we also keep catfish and snakehead fish outside the tilapia net culture. These bottom-feeders eat the residual feeds, minimizing waste and keeping settled solids moving toward the sump (the area of the system that retains water before the pump re-circulates it), through the pump and up into gravel beds or solids-removal filters. They also help control fry populations by preying on wandering hatchlings.

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Figure 2. Tilapia being held by Keith Mikkelson at Aloha House.

Feed Sources

Algae Bloom

For tilapia pond culture, where fish roam free or are in cages, algae should be the first feed considered. Ponds with a carrying capacity of 3 kg of fish/ square meter can benefit greatly from the addition of fertilizers, which can increase algal bloom and reduce the cost of inputs. Natural fertilizers are used in our system, but commercial fertilizers or purchased worm castings and composts can also be used. However, do plan to utilize farm-generated fertility before considering purchased inputs.

Fish that benefit from algae production (such as tilapia) have a mucus membrane on their gills that allows them to access the nutrients in phytoplankton as a food source. High in protein, unicellular algae grow in the upward column of the water profile, with access to sunlight. Fertility in the form of manures, compost, bokashi (a fermented anaerobic compost made of organic matter with beneficial microorganisms), or vermicasts will be sufficient to induce the algal bloom when sunlight is adequate in the tropical environment. We need less than 1 ton/hectare/production run of 120 days for tilapia if the amount of phosphorous is sufficient.

The Secchi disk (Figure 3) is a simple tool farmers can make to monitor the turbidity of their pond in order to determine the amount of algae growing and to better estimate how much fertilizer is required to optimize the algae production.

Keep track of your turbidity weekly, and adjust the amount of fertility inputs based on the Secchi reading (Figure 4). To maximize food production, the goal is to stay close to the 30 cm (12 in.) zone of turbidity (when you place the Secchi disk in the water to 30 cm, you should just barely be able to see it). Turbidity (and subsequently, algae production) depends on the amount of fertility, sunshine, cloudiness and day length. Remember, this is a biological system and it will adjust slowly as inputs are added or removed.

Bat guano can be a good source of organic phosphorus, and we have found that our local bat guano (from fruit bat dung) has a higher level of phosphorous than our ruminant manures (Table 1). On our farm, fruit bat manure produced the lowest rating on the Secchi disk, meaning the highest turbidity and, therefore, the highest algae production. This is because of the high phosphorous in their guano. As an alternative, we have also found our vermicasts to be more effective than ruminant manures as a phosphorus additive.

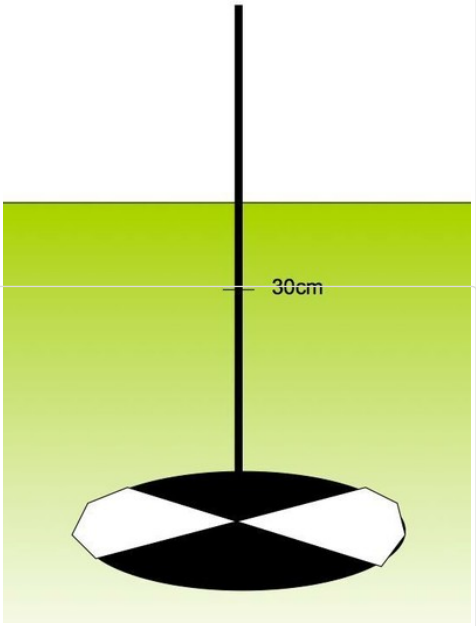

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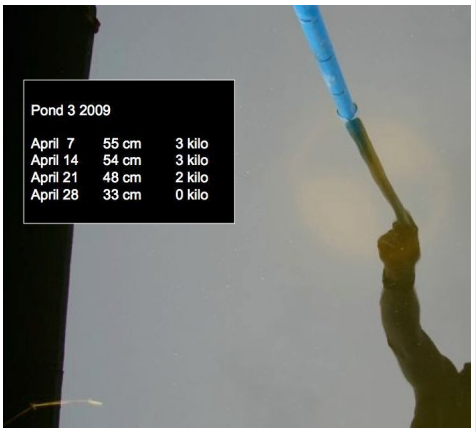
Figure 3. Secchi disk diagram showing black and white quarters and optimum depth for turbidity.



(/resources/9ffa76ae-1345-4dd1-94f4-fc35e74960b5)Figure 4. Secchi disk in action - note the ability to see the black and white quarters. Table shows growth in algae as a response to added amounts of natural fertilizer (in kg).

Sabang Bat Guano	ppm	%
Nitrogen (N)	2800	0.280
Phosphate (P_2O5)	18100	1.810
Potash (K_2O)	3800	0.380
Manganese	440	0.044
Iron	519	0.052
Copper	36	0.004
Zinc	206	0.021
Vermicast	**ppm**	**%**
Nitrogen (N)	5100	0.510
Phosphate (P_2O5)	8200	0.820
Potash (K_2O)	2500	0.250
Manganese	110	0.011
Iron	678	0.068
Copper	6.1	0.001
Zinc	206	0.021
Bokashi	**ppm**	**%**
Nitrogen	7600	0.760
Phosphate (P_2O5)	5000	0.500
Potash (K_2O)	8100	0.810
Manganese	50.99	0.005
Iron	175	0.018

Copper	3.37	0.000
Zinc	28.17	0.003
Calcium	1.41	0.000
Magnesium	0.16	0.000

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Table 1. Nutrient concentrations of Aloha House's 1) Bat Guano, 2) Vermicast, and 3) Bokashi for use in algae production.

Commercial Fertilizer

Recommendations for synthetic fertilizers vary based on water hardness and phosphorous source. That said, urea and a phosphate fertilizer are often recommended if composts or manures are not obtainable. Super phosphate fertilizer at 0.625 kg/100 m^2/week is recommended for algae feedstock for tilapia production (Bocek, NA). However, in our all-natural system, we find composts (if bat guano is not available) to be more than adequate at producing algae, thereby lowering costs and minimizing the impact on surrounding soil and water systems.

Floating ferns, such as azolla (*Azolla* sp.), duckweed (various genera and species) and even salvinia (*Salvinia* sp.), can be utilized if they are cultured separately from your fish. Omnivores like tilapia and koi readily eat large quantities of these greens as a feed source. Options for production include separate dedicated ponds, containers or troughs, as well as net-protected rafts within the fish culture. Remember, any fodder crops grown within the fishpond must be protected or isolated from the fish, otherwise the fish will overgraze and deplete the crop! In addition, if the goal is algae production, plants growing on the surface will block sunlight and prevent growth of algae and other phytoplankton. It is difficult to produce both protein sources (i.e. algae and water plants) to their full potential in the same column of water.

Many floating ferns and aquatic plants are high in protein. In experimental trials comparing *Lemna minor* (common duckweed), *Ipomoea reptans* (kang kong or morning glory), *Trapa natans* (water caltrap) and *Salvinia cuculata* (often mistaken for Azolla) in India, both duckweed and morning glory had good feed conversion ratios and high protein: 28% and 32% respectively (Kalita et al., 2007). These are great fodder crops when grown independently of the fish crop so as to ensure a regular harvest. Azolla (*Azolla caroliniana*), with a reported protein range of 19-30%, is another fast-growing floating fern that I wish had been included in the India study. A fish farmer must be careful not to overharvest these crops, however, so that sustainable production can be maintained. A general rule of thumb (under ideal conditions) is to harvest no more than half of the floating biomass per week (or 1/7 of the total biomass per day). The trick is to keep it in the rapid vegetative stage, so be sure to monitor which way is more productive in your system. Azolla tolerates moving water better than duckweed. Salvinia is the fastest growing, but can be very invasive.

In our floating feed pellets (described below), salvinia creates more buoyancy than azolla or duckweed, owing to its airy structure. Salvinia is fermented with the other higher protein ferns, rice bran, copra meal, fishmeal and molasses to create a high-quality floating feed. We find the air cavities in the salvinia are crucial to the buoyancy of our feeds. We will discuss the benefits of floating feeds later.

Pelletized Feeds

As farmers seek to intensify fish production, concentrated feeds are a method worth considering. However, the problem for many fish farmers is the cost of commercial feeds. The ECHO Technical Note "Fish Feed" (ETN, 2010) lists a variety of supplemental feeds that are commonly used: rice bran, mill sweepings, termites, table scraps, maize bran, and many green leaves (Murnyak, 2010). For feeding pelletized feeds, the Bureau of Fisheries and Aquatic Resources in the Philippines indicates that a progressive feeding schedule should be followed to optimize fish growth and profits (Table 2). It is best to match feeding to a specific age/weight of fish, and adjust the size of the feed pellets as the size of fish stocks increase. If fish are not graded, you must match pellet size to the smallest fish in the cage or pond, to ensure they can compete with the bigger fish during each feeding session. If you always stand in the same place and place feeds in the same area of the pond or tank, the fish will be trained to feed whenever you appear. This is helpful in monitoring the growth progress of your fish. Do not overfeed or feed off-schedule, as the fish will tend to eat your profits. Profits are lost because Tilapias have an ability to bypass their digestive tract while gorging on expensive feeds. This results in wasted feed and lower profit for the fish farmer. Farm-made feeds require proper drying and handling in order for the end products to perform well. A sustainable feed-drying system must be thought out in advance of any attempt at feed production.

Bureau of Fisheries and Aquatic Resources (B.F.A.R.) Feeding Rate and Schedule				
Age of Fish (Days)	Type of feeds	Feeding Rate of Body Weight	Feeding Frequency	Ideal Weight of One Piece
1 - 15	fry mash	8.0%	4x day	6g
16 - 31	fry mash	7.0%	4x day	25g
32 - 46	starter	6.0%	4x day	36g
47 - 61	grower	5.0%	3x day	50g
62 - 76	grower	4.0%	3x day	72g
77 - 91	grower	3.0%	3x day	100g
92 - 105	finisher	2.5%	2x day	121g
106-120	finisher	2.0%	2x day	150g

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Table 2. Philippines Bureau of Fisheries and Aquatic Resources feeding table designed to help growers optimize fish growth and profits.

On-Farm Production of Fish Feed

With experimentation and careful recordkeeping, a fish farmer can produce his/her

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Figure 5. Making your own high-quality floating feed does not have to be difficult.

own high-quality feed (Figure 5). In many countries, readily available meat grinders and pelletizers have made it possible to create economic floating feeds for tilapia, koi or catfish. Our unit was obtained in Chinatown, Bangkok, Thailand. It is an un-branded stainless steel auger-driven meat mincer manufactured in China. We assembled it on a table

at home and mounted it with a 1 hp motor (Figure 6). Before beginning, make sure you have a range of plate sizes to extrude your feed, so that feed and stock size can match. The sizes we use are in the 2-8 mm range for our 300-500 gram tilapia production. When we finish making the feed, we immediately dismantle and clean the auger, blade and plates. When done with a good auger-type grinder, very little effort is spent in the production of feeds (Figure 7). At Aloha House, two

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(/resources/c0217a72-5a4a-4bca-b745-13e3cdab637f)Figure 6. Meat grinder used for extruding fish feed.

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Figure 7. Extrusion of farm-derived fish feeds.

people can produce ten trays (approximately 45 kg) of moist feed in less than one hour. One operator feeds the mix into the auger from a tray and periodically tops off the tray to ensure a steady flow through the grinder. As the feed is extruded, a second operator uses a scoop to

spread the wet pellets in a thin layer on a drying rack (Figure 8), then loads it in the solar dryer (Figure 9).

For drying racks, we use bread trays with a screen liner riveted to the bottom of each. Make sure airflow is adequate for rapid drying on sunny days. Box or wood frame dryers work well if wall thickness is minimized to save space. Our solar dryer is rooftop mounted and takes two or three days to dry

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Figure 8. Setting out pelletized feed on a drying rack made from bread boxes and window screen.

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our feeds, depending on pellet size and cloudiness. The general design of our dryer incorporates a sheet of UV-treated 0.2 mm (0.008 in.) greenhouse plastic clipped to a welded G.I. frame.

When dry, all feeds are sealed in 20-liter (5 gallon) pails with lids to ensure dryness and freshness. Eight percent (8%) moisture content can be achieved if conditions are ideal. Summer days with lots of sunshine are helpful, but during rainy cycles, producers may not be able to avoid cloudy days. Our solution is to take advantage of sunny periods and even create a surplus for rainier periods. The old adage “make hay while the sun shines” applies doubly in the tropics for feed production!

Benefits of Fermentation

Digestibility and shelf-life of fish feed are enhanced through the activity of certain beneficial microorganisms during the production process. According to findings from one study, the use of microorganisms increased the crude protein in copra from 17.24% to 31.22%. The amino acid profile was also found to be greatly improved (Cruz, 1997). *[Note: In addition to fermenting fish feeds, at Aloha House we also ferment our feed for chickens, ducks, and hogs with the help of diverse probiotic groups of microbes. However, we do not use fermentation for our ruminant feeds. (Creating on-farm feeds for other animals will be covered in another EAN)].*

(/resources/78f5db24-123a-46ab-bbf0-2194334e1b37)Figure 9. Solar dryer for pelletized fish feed at Aloha House.

When fermenting your feed, it is important to use proven strains that are not crosscontaminated with wild pathogens. We use EM-1, a commercial product that undergoes laboratory testing and is approved for aquaculture by the Bureau of Fisheries and Aquatic Resources in the Philippines. EM-1 was formulated by Dr. Teruo Higa in Ryukyus University, Okinawa, Japan, and is readily available in over 100 countries. The product includes cultures of robust lactobacilli, photosynthetic bacteria, beneficial yeast and more. They will feed on sugars and other carbohydrates, while creating secondary metabolites that increase the nutrient range of the feed. My book, *A Natural Farming System for Sustainable Agriculture in the Tropics,* is a user's guide to EM technology. It is available online as a free PDF download or can be obtained through ECHO bookstores. Even CO_2 is produced during fermentation, helping to increase the floatation of our feeds! Cheese or yogurt whey, sourced from a local creamery, could be used to some effect if EM-1 is unavailable. Start small by substituting the whey at the same rate as EM1 and adjust upward if it does not have an effect. Good fermentation should create a sweet and sour smell after 2 weeks. If foul odors such as rotten eggs (sulfides) or rottenness occur do not feed to your fish. It still has value after you remediate. Just discard your SMALL failed experimental batch to the compost heap and use as fertilizer.

We pre-mix all our dry materials (rice bran, copra meal) and then add the greens (salvinia, azolla, duckweed), EM-1, and molasses diluted in water. After complete mixing of all ingredients to 30-50% moisture content, we allow it to stand in an open container for three to six hours before extruding it through the machine. Letting it stand will ensure more uniform moisture content of the materials and achieve a better end product. A simple field test for moisture content in the 30-50% range is the ball test. Take the feed in two hands and form a ball with mild pressure. If it does not stick it is too dry. If it is dripping wet it is over the moisture target. The pellets will continue to ferment while drying and even in storage, to a lesser degree, until all moisture is evaporated. As long as you have a dry pellet that can crumble under pressure and not stick to each other, you are in the 8-10% moisture range, which is ideal after drying. It is not necessary to go below 8% moisture.

Formulas for Tilapia

When creating your feed, be sure to measure and weigh each component accurately and record the performance of each trial mix. Keep some of your fish on the current feed system (control) so you have something to check against. Compare the weight of fish with your new feed and control after one month to see how it performs. We encourage you to use what is available in your area and learn to optimize your own blend based on regular testing. A spreadsheet is useful for adjusting inputs and formulating feeds that will be worth your while. After many months of record keeping, you will be able to evaluate the benefits of your farm-generated feeds. We find that if we formulate the mix based on crude protein, the rest takes care of itself. Earlier I discussed floating ferns as a fresh feed; for bio-diversity and a broader range of inputs you can use a combination of duckweed, azolla and salvinia added to your low cost, high quality pelletized feed. Learn to culture these ingredients. Purchasing them will eliminate your savings! Spirulina (a cyanobacterium, also known as bluegreen algae) is another possible alternative or addition to floating ferns. Over 30% of worldwide spirulina production goes to non-human feed stuffs (Belay et al., 1996). Other substitutions have been explored with mixed results, including water hyacinth in Nigeria (Igbinosun et al., 1988). I would not recommend experimenting with water hyacinth and have not been impressed to do so myself. But if you do please send us your results!

Rice bran should be D1 from the "Cono" mill. Other lesser grades (D2 to D4) should be avoided due to the high quantity of cellulose. See the Rice Mill Primer in the notes section of my book for more information (Mikkelson, 2005). Other brans (corn, wheat etc.) can be used, but beware of compromising crude protein levels. Most modern corn varieties contain half the crude protein of rice bran. Top quality rice bran is 12% to 14% crude protein! Copra meal contains up to 24% crude protein, but a caution is in order: copra meal (like Black Soldier Fly larvae) contains high-quality protein but is also high in fat and should not be used excessively. High fat will sacrifice weight gain due to lower carbohydrates and protein.

Vitamins and Minerals

Finely crushed rock powders from gravel mills will have a range of minerals to supplement any deficiencies in cut greens or floating ferns (Murnyak, 2010). We use our organically-grown moringa at 1% by weight of the mixture if we do not have rock powders. Finely ground livestock-grade limestone can also be added for bone growth support. When integrating fish and plants in an aquaponic system, the fertility for plants is derived both from the fish excrement and wasted feed (tilapia waste 10-20% of their feed, which is converted by bacteria into plant-usable nutrients). In Australia, 40-55 grams of carnivorous fish feed will fertilize 1 square meter for horticulture using the raft method, whereas 60-100 grams of tilapia feed (because tilapia are omnivores) will be needed for the same level of production (De Dezsery, 2010) (Figure 10).

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Figure 10. Tilapia next to aquaponic plant grow-bed at Aloha House.

To Float or To Sink?

Do not be overly concerned with whether or not your feed floats or sinks; studies are finding protein to be more important than buoyancy! The high-energy cereals used in commercial feeds sacrifice the Feed Conversion Ratio (FCR). FCR is calculated by the ratio of weight gain/weight of feed consumed. Younger fish may gain almost 1 gram for every gram consumed (FCR 1.0), while older fish will need to eat 2 grams of feed to gain 1 gram in weight (FCR 2.0). The digestible, convertible nutrition in the feed is most important. We have studied the feeding habits of tilapia and koi in our glass observation tanks, and we find that they recover all of the feed if detritus levels are not excessive. In fact, Cruz et al. (2001), found in one study that floating feed did not perform as well as sinking feed. They concluded, “Sinking pellets promoted significantly higher growth rate, bigger fish and gave better FCR in Nile tilapia juveniles than those fed with floating pellets. The better performance of fish fed with sinking pellets may be attributed to the higher crude protein content (42.05%). Similar results were obtained by Gur (1997), who reported that the average daily gain and FCR at a crude protein level of 40% were significantly higher and better than at 30%. He concluded that the crude protein levels for optimum growth and FCR were from 40 to 45% for Nile tilapia with initial mean weight of 13 g.” (Cruz et al., 2001). Higher protein can be obtained for carnivorous fish by increasing the fishmeal in the mixture, but be sure that your source is mercuryfree. Black Soldier Fly larvae, with a protein content of 45%, can also be used as a high-protein additive (De Dezsery, 2010), but must be dried before mixing into your fermented feed.

Starting Formula

Here is a good starting point for creating your own feed (Table 3). Be sure to keep notes and adjust the ingredients based on your available feedstock and the performance of your farm-made feeds! Costs listed are relevant for your location but might differ elsewhere.

Tilapia Feed with Fish Meal & High Crude Protein Greens							
	Crude Protein	Cost P / 50 kg Sack				Cost	
Commercial Feed	32.00%	1,300.00				26.00	P / kg
Fermented EM Feed	32.31%	512.34				10.25	P / kg
Ingredient	Crude Protein	Weight (kg)	%	Cost P/kg	Crude Protein Units	COST	
Rice Bran(D1)	14%	28.00	32.2%	14.00	3.92	392.00	P
Copra Meal	22%	8.00	9.2%	9.00	1.76	72.00	P
Fish Meal	72%	17.00	19.5%	25.00	12.24	425.00	P
Duck Weed	44%	3.00	3.4%	0.00	1.32	0.00	P
Az olla	44%	10.00	11.5%	0.00	4.40	0.00	P
Salvania	22%	20.00	23.0%	0.00	4.40	0.00	P
Moringa	18%	0.30	0.3%	1.00	0.00	0.26	P
Livestock Lime	0%	0.10	0.1%	8.00	0.00	0.80	P
Rock Dust Minerals	0%	0.26	0.3%	1.00	0.00	0.26	P
Charcoal - Fine	0%	0.26	0.3%	1.00	0.00	0.26	P
Molasses	3%	0.10	0.1%	8.00	--	0.80	P
EM	1%	0.10	0.1%	8.00	00	0.80	P
	Wet Weight	86.96 kg	100.0%		28.09	10.25	P / kg
	Dry Weight	60.87 kg				14.64	P / kg