Animal Integration & Feeding Strategies for the Tropical Smallholder Farm

Approaches and Methods for Increasing Sustainability & Profitability

by Keith O. Mikkelson

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Preface

I first visited the Mikkelson's Aloha House Orphanage and Sustainable Farm in Puerto Princesa, Philippines, back in 2013, when ECHO Asia was co-hosting a Sustainable Agriculture Workshop and also conducting research on the continued effectiveness of the Small Farm Resource Center.

While at their site, I was struck by the intentionality and efficacy of site planning, organic best practices, nutrient cycling, water recovery, and creative solar energy usage. I was also struck by the integration of animals into every facet of their system, and the way that they were able to use animals for various functions and saw them as beneficial integral components in their system and not simply as protein storehouses like modern industrialized agriculture tends to view animals. It was quite the inspiration to see the Aloha House property and how it produces an impressive amount of food in a small area, with very few off-farm inputs.

This booklet was borne out of a need to help smallholder farmers re-integrate animals into their systems and use nutrients and energy wisely in order to reduce external inputs, increasing sustainability and profitability. This booklet is based on five of Keith's prior articles that were written for ECHO Asia Notes, which include AN #20 Fish Feed, AN #25 Hog Feed, AN #28 Poultry Feed, AN #31 Ruminant Feeds, and AN #35 Animal Integration.

It is our hope that this work will inspire and guide how the integration of animals and on-farm products for animal feed creation can reduce dependency on external (often costly) inputs for the farm, increasing sustainability and profitability for farmers.

Abram J. Bicksler, Ph.D.

Director, ECHO Asia Impact Center

Chiang Mai, 2018

Author Bio

Keith Mikkelson is the Executive Director of the Aloha House Orphanage and Sustainable Farm in Puerto Princesa, Palawan, Philippines. Along with his wife, Narcy, Keith has practiced sustainable farming at the Aloha House Orphanage for 15 years, producing nutritionally dense, sustainable, farm-derived food that is consumed both at the orphanage and by local customers.

As well as writing for ECHO Asia Notes, Keith is also the author of *Sustainable Agriculture In The Tropics*, a book that shares the many techniques and operations happening at the Aloha Sustainable Farm. Both of these books are important works for tropical agriculture, addressing the day-to-day operations of a farm or garden. *Sustainable Agriculture* is extremely useful and contains planning materials that takes into account logistics as well as timetables. Both books, *Sustainable Agriculture* and *Animal Integration,* are great companion pieces and can be accessed in hard copy at the ECHO Asia office in Chiang Mai, Thailand as well as PDF at ECHOcommunity.org and lulu.com/mik

Aloha House staff, children & animals, April 2019

Table of Contents

List of Figures

List of Tables

A drought tolerant bovine grazes humidicola grass (*Brachiaria humidicola*) under well-spaced coconut in the Philippines. Integrating cows in this way saves on grass cutting chores and other costs common in the industry.

Chapter 1:
Livestock Integration on the Tropical Smallholder Farm

Introduction

One of the best things that you can do to complete your sustainable farm or garden is to balance it with a small livestock unit. Livestock integration is fundamental #10 in my book *Sustainable Agriculture in the Tropics.* If you read *ECHO Asia Notes*, chances are good that you are involved in some way in farming or gardening. Livestock will produce low cost, high quality fertilizer, while also yielding food to eat or clothing material to wear. Although scientists have attempted to replicate the benefits of traditional integrated livestock systems, the quantified results are not always easy to show in field trials.

On the Aloha Farm in Puerto Princesa, Philippines, we calculate that our hogs typically bring in a net profit of $30-40 USD per head. With 12 to 15 units in a staggered harvest, they have the potential of bringing in 200-300 USD profit per quarter. In addition, we started using 20-liter pails to measure the volume of manure from the hogs, and found that manure production was over 25 m^3/quarter for a batch of 12 to 15 hogs. The manure composts down to 10 m^3/quarter, which is enough to fertilize a hectare of sweet corn—earning us $300 USD profit.

Beyond that, we found that the crop residue from the corn stover could be made into biochar, fed to goats, or composted with more hog manure to continue the cycle. We are much more diverse than most farms, but I hope this example helps you begin to see the value associated with an integrated crop-livestock model. The animals on your farm have tremendous potential to increase the fertility of the overall system without the need for expensive external inputs.

Traditional Integrated Systems

According to the Food and Fertilizer Technology Center (1999): "Farmers tend to integrate livestock and crop production better than most scientists do!" We can learn a lot from these existing systems and their years of trial and error (FFTC 1999). Sajise points out that "Traditional systems already combine various mixtures of livestock species and crops. The challenge is to increase the productivity of traditional systems, so they may produce higher [amounts of] usable biomass while conserving the natural resources on which the whole agricultural system depends" (FFTC 1999). According to the International Rice Research Institute (IRRI), in regions such as Asia, mixed crop-livestock systems can probably be regarded as the foundation for the production increases that improved food security and helped alleviate poverty (Sombilla and Hardy 2005).

Paris (1992), summarizing the results of rice-based crop- livestock farming systems research in the Philippines and other Asian countries, enumerated crop-animal interactions as follows:

1. Use of animal power in crop production, transportation, and processing; and use of crop by-products (straw, bran, and residues) by livestock and poultry.

2. Use of animal manure to improve land productivity and cut input costs.

3. Minimizing production risks by combining crop and livestock enterprises.

4. Small-farm household consumption of milk, meat, and eggs, thus substantially improving human nutrition and health.

5. Sale of livestock and poultry and their products to improve and stabilize farm income for the purchase of cash inputs and to offset household expenditures, such as school fees, social obligations, and health care.

However, the main issue in crop-animal interactions is the lack of methodology for measuring the benefits derived from them.

Getting Creative with Integrated Crop-Livestock Options

Properly managed livestock can bring the tropical farmer higher profits than some market vegetables and most grains. In permaculture, we say "integrate instead of segregate!" An example of this is the way farmers integrate their grazing livestock into seasonal cropping patterns. In traditional upland farmland systems, cattle and goats are left to graze in the forest or taken up onto higher ground away from the cropland during the growing season. When the harvest is over, the animals are brought back to the village to graze on the fallow croplands during the dry season (FFTC 1999). At the Aloha House Farm, we raise and integrate goats, chickens, ducks, cattle, and hogs (Figure 1.1). For example, our goats graze pasture and browse as well as feed on legume shrubs, and we feed some crop residues to the goats (Figure 1.2). With the integrated system, we are able to eliminate many feed costs and (with the manure we collect) also eliminate many fertilizer costs. We cut and carry fresh feed stock for goats, cows, chickens, and hogs; it requires labor, but we are able to minimize inputs.

Figure 1.1: *Efficient daily harvest of cut-and-carry legumes for goats, cows, and hogs will reduce feed costs.*

Figure 1.2: *Gliricidia and leucaena fed on racks to goats.*

At the Aloha House Farm we recommend that you allow animals to graze, if space allows. However, this is not always feasible in smallscale settings or urban environments. Where grazing is not an option, you can use various grains as supplemental feed. Consider fermenting the grains with beneficial microbes to increase feed conversion; we find that the fermented grains also act as probiotics, minimizing the need for medications.

Omnivores such as hogs, chickens, and ducks also do well with some silage sources; we use Effective Microorganisms (EM) to initiate our fermented feeds.

The live microorganisms in EM synthesize natural vitamins and make available health-enhancing components that can protect livestock. For us, the EM costs are far less expensive than antibiotics and vitamin shots would be; and have even enabled us to remove the need for any antibiotics in our system. We spray all pens and barns weekly with EM to minimize odors and flies. The high number of beneficial bacteria begin to exclude pathogens through competition. According to Higa and Parr (1994) EM-1 is a commercially available blend that contains three types of microorganisms:

1. Lactic Acid Bacteria - This family of bacteria are also used to make yogurt and cheese. The bacteria convert sugars into lactic acid. In the process, they lower the pH, inhibiting the growth of pathogenic microbes and make it difficult for methane-producing microorganisms to survive.

2. Yeasts - These are single-celled fungi such as those used in making bread and alcohol. They kick off the process of fermentation.

3. Photosynthetic Bacteria - These bacteria allow the other microbes in the mix to coexist. They use photons to metabolize organic and inorganic substances. According to Drs Higa and Parr, (1994) the photosynthetic bacteria "perform incomplete photosynthesis anaerobically" (i.e. in the absence of oxygen). Since the process of photosynthesis yields oxygen as a byproduct, these bacteria help provide oxygen to plant roots. Photosynthetic bacteria are also beneficial for their ability to detoxify soils, for example by transforming substances like hydrogen sulfide into useful compounds, and for their ability to fix nitrogen.

As part of our animal feeding system, we cut and carry daily. We feed the goats in their enclosures until the sun dries the pasture, making it safer for them to graze; in our area, parasites infect the rumen when goats graze on wet grasses. We feed the bucks, kids, and does from our established fodder banks and contour hedgerows of Tick-trefoil (*Desmodium rensonii*), Malabalatong (*Flemingia congesta*), (*Indigofera*), Kakawate or Madre de Cacao (*Gliricidia sepium*), Ipil-ipil (*Leucaena leucocephala*), and Acacia (*Mangium acacia*). Sometimes our goats even eat some of the bark. Please refer to chapter 5 for more information.

As they eat, a small herd of goats can create huge piles of leftover sticks and branches that can be dried and used for cooking fuel. This practice of cut and carry combines gathering feed for the goats with the daily chore of scavenging for fuel, demonstrating another great benefit of integrating livestock on the farm. Although it can be difficult to quantify the economic value of feed and fuel, you will find your labor time reduced by acting in intentional ways.

Table 1.1: *Common Livestock Manure Sources and Nutrient Estimates (NRCS 1995).*

Livestock Type	Total Manure	Nitrogen	Phosphorus
	lbs/day/1000 lb animal unit		
Beef (high forage diet)	59.1	0.31	0.11
Dairy (lactating cow)	80.0	0.45	0.07
Hogs (grower)	63.1	0.42	0.16
Chickens (layers)	60.5	0.83	0.31
Chickens (broilers)	80.0	1.10	0.34
Turkeys	43.6	0.74	0.28

By properly composting biomass on the farm, we increase our production of grains, vegetables, and herbs, reducing fertilizer costs and increasing yields. This is the main benefit in our system in the Philippines, but we will explore other benefits as well, including the production of biochar from waste.

Integrated Aquaculture with Plants

In addition to the cut-and-carry systems we use for our larger livestock, we have experimented heavily with a scaled down monogastric fish production system adapted for aquaponics where we raise tilapia. Ducks also participate in the aquatic system by swimming, foraging, and bathing in designated ponds linked via plumbing and recirculating water but not containing the fish crop (Figure 1.3). We use the wastewater for simultaneous vegetable production. Please see chapter 2 for more information. Not all farmers succeed with this kind of system, so if you experiment, begin with caution and on a small scale. For example, Little and Edwards (2003) warn of the failure of scaled-down modern systems integrated with aquaculture. "Small-scale, feedlot monogastric-fish systems have been shown to be tech-

Figure 1.3: *In this aquaponics system, fish and plants are reared separately but are linked together in a closed loop water recirculating system. With the help of beneficial microorganisms and proper design, the fish fertilize the plants and the plants filter the water for the fish.*

nically viable in on-station, researcher-managed trials. However, sustained adoption of these types of systems by farmers has been rare" (Little and Edwards 2003). You can think of any livestock system that is confined and dependent on mainly purchased input as a "feedlot" regardless of size. The economy of scale can make small operations unsustainable because of the low profit margins and cost of purchased inputs.

Figure 1.4: *Top Harvest Vermicasts – weekly castings are top harvested until ½ of the composted manures are depleted. Then, two-week old hot EM composted manures are added to the vermiculture bed.*

Vermicompost Production

Using manure from our animals, we have integrated the production of vermicompost into our agricultural system (Figure 1.4). Our worms are fed pure composted manure from the cattle, goats, and hogs. The resulting vermicasts are mixed into potting soil for use in our nursery (our potting soil is made with 20-25% pure vermicasts). This critical part of our herb and vegetable production has always been worth the added management. We can harvest 6-10 liters of vermicast per m^2 using African night crawler worms (Mikkelson 2015). Other projects throughout the tropics have also integrated this manure-vermicomposting approach, including the Mindanao Baptist Rural Life Center in the Philippines (Tacio 2014; Capuno 2010).

Managing Nutrient Cycles

When farmers begin to integrate livestock with crop production, the animals' waste will increase yields the most (Figure 1.5). In our system, only manure in barns and night-time enclosures is gathered and mixed with other materials for compost. Manure from penned animals is easy to collect. For grazed livestock, any manure in our rotational grazing systems stays in the field to fertilize the pasture and contribute to the ecosystem stability. The manure will be incorporated by microorganisms, beetles, earthworms etc. without any further human intervention. We have copious amounts of manure available from our barns, and need not spend the additional time and effort in the field gath-

Figure 1.5: *In Thailand, dairy cattle co-op members share resources and grow napier grass and legumes, and also sell silage to each other. The manure is used for fertilizer.*

Figure 1.6: *This Heifer Thailand biogas unit at Aloha House, Philippines, is a floating drum digester.*

ering manure. If you are just getting started and in need of manure for composting, you may decide to gather what you can. However, in the future you will want to find a way to collect manure in the livestock enclosures, in order to conserve time and labor.

If you want to convert a feed-lot type enterprise into something more sustainable and you wish to use more of the on-farm resources, you will need to find ways to use the waste stream. Above are some estimates of manure production for several types of systems. Heifer Thailand has a well-designed biogas unit that can use liquid manure to produce methane for heating/cooking (Meyers 2012; Figure 1.6). ECHO has other options for biogas digesters, available on www.echocommunity.org. For example, see a presentation by Wilkie (2016) and other resources at https://www.echocommunity.org/en/search?q=biodigesters

On our farm, we always compost our manures aerobically to generate the heat that eliminates pathogens and diseases. Aerobic composting, or "hot composting," allows certain universal thermophilic microorganisms to break down the organic waste into usable, stable compost. Temperatures above 60ºC in your compost pile will kill weed seeds and pathogens (Richard 1992). Monitor the temperature daily until you get a feel for it. Place a machete or metal rod (Figure 1.7A, page 18) into the core of the compost pile for 10 minutes. After you pull it out, use an infrared thermometer to read the temperature of the metal (if you use your hands, it should be uncomfortably warm to the touch) (Figure 1.7B, page 18). We turn our compost piles once a week for a total of three weeks. You can read more about compost in my book, in the chapter on Fundamental #4: Composting.

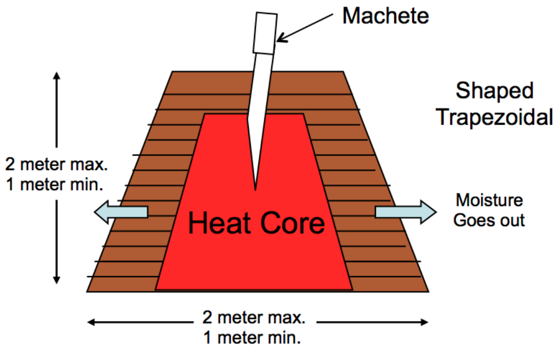

Figure 1.7A: *When hot composting tropical manure, crop residue, weeds, and temperature should rise from 25-30º C in the beginning of the composting cycle to >60º C, in order to safely eliminate pathogens and diseases.*

Figure 1.7B: *Measuring temperature inside a working compost pile.*

The Added Step of Biochar Production

To take your soil management to the next level, consider utilizing woody waste materials and husks for biochar production. Through a controlled process called pyrolization (from the Greek, meaning *fire separating*) you can convert the woody carbon matter (lignin) into a highly porous, nutrient-holding, biologic powerhouse and soil conditioner. We dry the sticks and branches from our cut and carry goat feed waste, and pile them in a circle around a centralized pit (Figure 1.8). When the sticks are adequately dried of water vapor, we top light the pile. Place your kindling and dry paper or grass on the top of your stack and light from the top. Airflow will be drawn in from the bottom of the pile and preheat on the way up through the coals as they burn downward. This increases efficiency and gives a higher yield of biochar. If the sticks are compressed, the pit will not allow airflow from below and block air from the bottom. We use dried *Cogon imperica* grass as an accelerant to ignite the top of the pile, thus igniting the Top Lit Up Draft (TLUD) biochar system in the pit. The TLUD process burns the combustible oils and gases while minimizing smoke and producing a clean burn. A migratory pyrolytic front efficiently works its way down the pile and is doused with water to harvest the char before allowing it to become ash (Figure 1.9).

Figure 1.8: *Cut and carry sticks and branches are dried after the goats eat the leaves. Once dried, the woody material is efficiently converted into biochar by top lighting the pile.*

Some trial and error is required before you know when to stop the burn—you need to stop it before all of the wood is converted, and not allow it to burn to ash. We have a permanent pit surrounded by various piles of sticks drying at different stages (the leftovers of our cut and carry for our goats; Figure 1.10), and have found that we require no clunky, rusting metal retorts or machines.

Biochar can also be made from other forage crop residues, such as corn stover or napier grass (*Pennisetum purpureum*), but stacking is difficult without a cage. We use steel matting formed into a cylinder to form a TLUD pyrolizing cage. We also pyrolize old coconut husks into a nice crumbly biochar that works well in our raised beds for herbs and vegetables.

Figure 1.9: *To minimize water consumption during the dry season, water is already in position to douse and "activate" the corn stover in a pyrolizing cage over an earthen pit.*

Figure 1.10: *Sticks are piled in weekly batches to ensure uniform drying. They are TLUD pyrolized when moisture content is 20-30%. When there is moisture content of 20-30%, sticks will be brittle or crisp, when you bend them they crack and look dry with no green layers. Also if you see the stick bark blistering and bubbling on the end when you pyrolized them, they are too high in water content. At 20-30% MC the residual moisture is mainly comprised of oils, not water, which aids in the conversion of the lignin, cellulose, and hemicellulose from the woody material into char without becoming ash.*

Activating and Charging Biochar

Biochar can be made through many different methods, but the farmers we work with are most concerned with ease of operation and efficiency. However you make it, you should "activate" the biochar, and charge it with nutrients and microbes. We activate biochar by dousing it with water at the end of the production cycle. Water saturation activates the charcoal by attaching electrons so as to prevent the biochar from tying up nutrients in the soil. According to Craggs (2017), for biochar to have an immediate beneficial effect it must first be subjected to a process of "activation" (also termed inoculating or charging). Once activated, and subsequently charged with high levels of essential nitrogen and phosphorus, the many micro-fauna naturally establish, develop and grow in the maturing biochar compounds.

We also add biological and nutrient inputs, so that the biochar will not lock up the soil nutrients when we add it to the soil. We charge biochar with EM, compost tea, rich pond water, or fish silage. When needed, we also add mineral rock powders to supply trace elements and limestone for calcium. For more information, please see McLaughlin (2016).

There is some debate as to how long you should age biochar before use. Ranges from days to years are discussed but more research is needed. One researcher actually tested samples over a 15 month range and found higher CEC (Cation Exchange Capacity) in biochar after 15 months of field-aging. Overall, the 15 month field aging only had a significant effect on biochar pH and nanopore surface area, both of which decreased, while CEC increased (Mukherjee et al. 2014). We have found that, after activating and charging biochar, you can utilize it within days, but you may also bag it and stack it for future use; it can store for years. Don't be alarmed if you find various visible white molds colonizing the char. They should all be beneficial, if you used good quality compost or EM1 to charge your biochar. Check out my slide show on Biochar Options if you want to learn more (Mikkelson 2010).

Making Use of Locally Available Waste By-Products

To fully integrate your agricultural system, and to increase production and lower the costs of purchased inputs, look for ways to transform waste products into usable by-products. To fatten hogs, we feed them rice bran, fishmeal, and copra meal fermented in EM. Feeding crop residue to swine lowers our feed costs—a great benefit of livestock integration. We use sawdust beddings, to minimize stress and to allow natural rooting instincts that cannot be practiced on conventional cement flooring; the EM-treated sawdust bedding also helps minimize odors and flies (Figure 1.11). Our system is a no-wash operation; hogs maintain cleanliness when

Figure 1.11: *Eco-tourists are always surprised to visit our no-wash, odorless hog pens. Most people do not know that hog production can be an enjoyable, environmentally healthy practice.*

Figure 1.12: *Pond water from our duckponics system is used to grow feed for other livestock.*

allowed 2 m^2 each at the finishing stage (50 kg and up). There is no need to waste water or labor by hosing the hogs down twice a day. We also avoid smelly lagoons of effluent this way.

The hogs' manure production is plentiful, and it makes great fertilizer when properly composted. We harvest the manure daily and never remove the bedding, so the bedding gets more stable over time as the beneficial microbes colonize the bedding material. We do need to top up the bedding from time to time, because a small amount decays or leaves the system when we harvest the manure. Our hog fattening has been the most profitable of all our livestock units but we still maintain biodiversity within other livestock units (Figure 1.12).

Our free-range chickens eat small amounts of corn, sorghum, rice bran, copra meal, azolla, and duckweed, all fermented with EM1. The laying hens get crushed limestone as well as a calcium supplement. We give our chickens plenty of room to graze and scratch, and water is always available (Figures 1.13 and 1.14). The chicken enclosure has a bedding made from natural components, similar to the sawdust bedding of our swine systems. However, we use up to 50% rice hull and about 5% charcoal to stabilize the manure. We inoculate (spray) the bedding with EM1; the beneficial microorganisms keep the

Figure 1.13: *Chickens find shade while scratching and grazing the grasses in a papaya orchard.*

Figure 1.14: *Chickens eagerly forage for maggots from the fallen over-ripe fruits under dragon fruit plants, eliminating fly problems.*

environment healthy for livestock, reduce odors and minimize the number of flies. We never completely empty the bedding from poultry. At most we harvest 50% of the bedding and then mix in more fresh bedding materials. A mature bed is biologically stable and will provide a safe indoor habitat indefinitely if managed properly. If we removed all the bedding, the beneficial microorganism populations would have to start populating the bedding all over again. We have found that fresh bedding is not stable, and disease can be an issue in the beginning.

Conclusions

Integrated livestock systems can provide many benefits (Tables 2 and 3). With careful planning and by starting small, most farmers will be able to incorporate cows, goats, chickens, or hogs and improve the stability of their farm. Crop residues can reduce feed costs, and manure can reduce fertilizer costs. Manure can also be used to produce biogas for cooking or heating, to reduce costs on the farm. Grazing livestock can help manage weeds and improve soil health. With efficient management, you can turn even the waste stream from cut and carry feeds into the useful by-product of biochar. The key is to take on one appropriate technology at a time and to look for ways to minimize labor. Soon you will be able to safely expand as you adapt and apply lessons learned. Then you will be able to share with other farmers in your area!

Table 1.2: *Profits from Animal Integration into Agroecosystems (Carpenter-Boggs et al. 2013).*

Agroecosystem	Profits (USD) from animals (excludes profits from crops)	Source
Cattle grazing winter ryegrass cover crop	$170-$560/ha	Bransby, 1999
Cattle grazing winter ryegrass cover crop	$227-$323/ha	Hill et al., 2004
Sheep and broilers grazing for five months during spring-fall growing season	$2,077/ha	Lowy, 2009
Cattle grazing winter ryegrass or oat cover crop	$200/ha	Siri-Prieta et al., 2007

Table 1.3: *A Summary Table of Some of the Many Benefits of Crop-Livestock Integration (Kersbergen 2008).*

1.	A **source of nutrients** that can be used for direct application and/or composting. By combining livestock and vegetable production, the whole farm nutrient balance of imports and exports becomes more even.
2.	Along with nutrients, manure and compost applications tend to improve soil organic matter, **biological activity, and potential disease suppression**. This improved soil health will manifest itself quickly and include improved soil nutrient cycling, improved soil structure, better water holding capacity in droughty soils, and improved drainage in heavy soils.
3.	Livestock operations improve the potential for profit in lands that are in a "sod" rotation. Sod crops help to build soil structure (grass roots) and soil drainage (legumes/alfalfa). Sod crops high in legume content will also provide a source of nitrogen when those fields are returned to row crop production.
4.	Livestock provide a **use for crop residue and waste** or cull vegetable crops. This can help reduce disease while providing a "cheap" source of feed for livestock. Cows turned into a field of pumpkins in November utilize great feed and help vegetable producers clean up a field!
5.	Grain crops used by vegetable operators as cover crops can fit well into livestock rations. Winter grain crops provide fall **nutrient, catch weed control** in both fall and spring, and can be undersown with clover or other legumes to provide nitrogen in subsequent rotations and a sod crop establishment with minimum tillage.
6.	Adding livestock products to the marketing mix can help improve cash flow in the winter and add a new aspect to CSA operations.
7.	While not always discussed, successful "coupled" animal/vegetable operations can also **help to build community within a farm region**. Coupled operations also have the option of sharing machinery resources and labor during busy periods.

Animals living in harmony at the Aloha Farm.

Aquaponics center at the Aloha Farm.

Chapter 2:
Integrating Fish into the Smallholder Farm and the Creation of Fish Feed

Introduction

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.

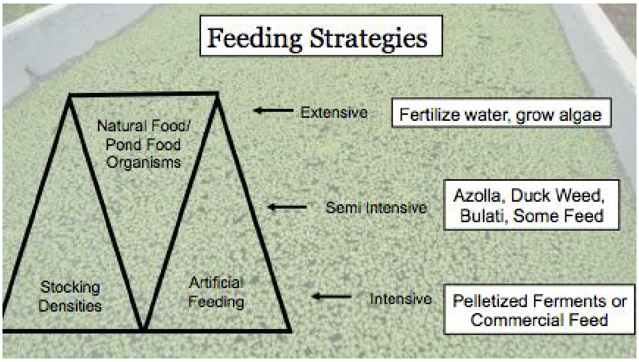

Figure 2.1: *Feeding strategies for fish, ranging from extensive to intensive.*

A farmer should first fully exploit his extensive (and more passive) existing systems, and then consider intensifying his overall operation (Figure 2.1, page 27).

Figure 2.2: *Tilapia being held by the author at Aloha House.*

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 2.2). 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.

Feed Sources

Algal 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 2.3) 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 2.4). 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.

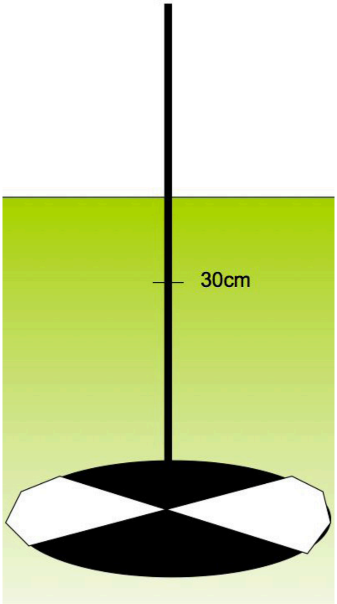

Figure 2.3: *Secchi disk diagram showing black and white quarters and optimum depth for turbidity.*

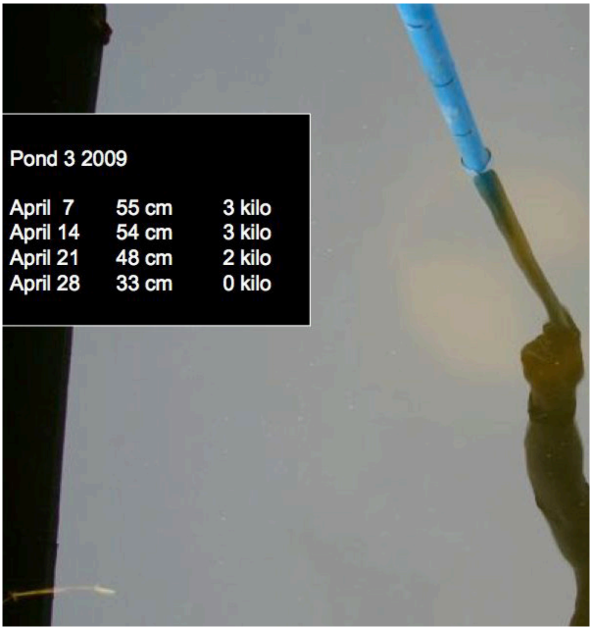

Figure 2.4: *Secchi disk in action - note the ability to see the black and white quarters. Table shows growth in algae as a response to added amounts of natural fertilizer (in kg).*

Table 2.1: *Nutrient concentrations of Aloha House's 1) Bat Guano, 2) Vermicast, and 3) Bokashi for use in algae production.*

	Bat Guano		**Vermicast**		**Bokashi**	
	ppm	**%**	**ppm**	**%**	**ppm**	**%**
Nitrogen (N)	2800	0.280	5100	0.510	7600	0.760
Phosphate (P_2O5)	18100	1.810	8200	0.820	5000	0.500
Potash (K_2O)	3800	0.380	2500	0.250	8100	0.810
Manganese	440	0.044	110	0.011	50.99	0.005
Iron	519	0.052	678	0.068	175	0.018
Copper	36	0.004	6.1	0.001	3.37	0.000
Zinc	206	0.021	206	0.021	28.17	0.003
Calcium	-	-	-	-	1.41	0.000
Magnesium	-	-	-	-	0.16	0.000

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 2.1). 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.

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 over-graze 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 common duckweed (*Lemna minor*), kang kong or morning glory (*Ipomoea reptans*), water caltrap (*Trapa natans*) 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.

Table 2.2: *Philippines Bureau of Fisheries and Aquatic Resources feeding table designed to help growers optimize fish growth and profits.*

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

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 2.2, page 31). 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.

On-Farm Production of Fish Feed

With experimentation and careful recordkeeping, a fish farmer can produce his/her own high-quality feed (Figure 2.5). 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 2.6A&B). 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

Figure 2.5: *Making your own high-quality floating feed does not have to be difficult.*

Figure 2.6: ***A&B*** *- Meat grinder used for extruding fish feed;* ***C*** *- Extrusion of farm-derived fish feeds;* ***D*** *- Setting out pelletized feed on a drying rack made from bread boxes and window screen;* ***E&F*** *- Solar dryer for pelletized fish feed at Aloha House.*

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 2.6, page 33). At Aloha House, two 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, then loads it in the solar dryer (Figure 2.6).

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 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 other chapters)].

When fermenting your feed, it is important to use proven strains that are not cross-contaminated 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 at ECHOcommunity.org 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 blue-green 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-available 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 2.7).

Figure 2.7: *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

Table 2.3: *Basic Tilapia feed using on-farm inputs. (Tacon, 2009)*

Tilapia Feed with Fish Meal & High Crude Protein Greens						
	Crude Protein	Cost USD/ 50 kg Sack				Cost USD/kg
Commercial Feed	32.00%	26.00				0.52
Fermented EM Feed-Wet	32.31%	10.50				0.21
Fermented EM Feed-Dry	32.31%	14.50				0.29
Ingredients	Crude Protein	Weight (kg)	% of feed	Cost USD/kg	Crude Protein Units	Cost USD/input by % of feed
Rice Bran(D1)	14%	28.00	32.2	0.28	3.92	7.84
Copra Meal	22%	8.00	9.2	0.18	1.76	1.44
Fish Meal	72%	17.00	19.5	0.50	12.24	8.50
Duck Weed	44%	3.00	3.4	0.00	1.32	0.00
Azolla	44%	10.00	11.5	0.00	4.40	0.00
Salvania	22%	20.00	23.0	0.00	4.40	0.00
Moringa	18%	0.30	0.3	0.02	0.00	0.005
Livestock Lime	0%	0.10	0.1	0.16	0.00	0.016
Rock Dust Minerals	0%	0.26	0.3	0.02	0.00	0.005
Charcoal - Fine	0%	0.26	0.3	0.02	0.00	0.005
Molasses	3%	0.10	0.1	0.16	--	0.016
EM	1%	0.10	0.1	0.16	00	0.016
Total Wet Weight		86.96 kg	100.0		28.09	17.843
Total Dry Weight		60.87 kg	100.0		29.09	17.843

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 mercury-free. 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 for Basic Talapia Feed

A good starting point for creating your own talapia feed is found on page 33 (Table 2.3). 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 our location but might differ elsewhere.

Conclusion

Small scale fish feed production can be managed by the careful use of locally grown and farm generated inputs. The more high quality inputs you supply yourself with, through efficient production and harvesting, will give you more profits through less capital input by producing your own feeds.

Azolla at the Aloha Farm.

Cut & Carry system at the Aloha Farm.

Chapter 3:
Integrating Hogs into the Smallholder Farm and the Creation of Hog Feed

Introduction

Farm-generated fertility contributes to more sustainable agricultural systems. 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 resources already available to them. For example, farmers might develop pasture using planned grazing for cattle; make hog feed from crop residue or dairy by-products (such as whey and skim milk); cultivate legume shrubs for cut-and-carry operations; and grow floating ferns and other water crops as feed supplements.

As densities of livestock increase, an industrious farmer finds ways and means to increase his farm's nutrient stream for the benefit of his system. This chapter will describe methods and techniques necessary for a smallholder farmer to succeed with farm-derived hog feeds. As you read, remember that

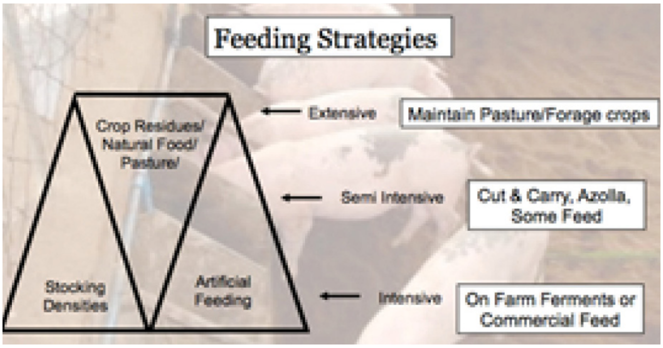

Figure 3.1: *Feeding strategies for hogs.*

a farmer should first fully exploit the extensive (and more passive) existing systems on the farm, and only then consider intensifying their overall operation (Figure 3.1).

[Author's Note: It is important to 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 Hog System

As we plan feed regimens for our pigs, we secure both on-farm and off-farm feed sources, in case of contingencies. This is important, but often overlooked. The advice from Skillicorn is noteworthy: "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, 1993). At the Aloha House, we purchase our fishmeal, rice bran, and copra meal from local sources. We also have a wide variety of legume shrubs, trees, and floating ferns to supplement any shortfalls in our purchased protein supply.

Our experience is with Landrace, Duroc, and Large White varieties, as well as other modern domestic breeds and crosses that respond well to intensive feed operations. These breeds experience consistent, rapid growth with our fermented feeds. Large White, Duroc and Land Race pigs are readily available from commercial growers and reliable back yard breeders, and they convert well to our system.

In our area of Palawan in the Philippines, native swine are an alternative to modern breeds. They are most economically raised on pasture with planted forage crops and tubers. In a pasture system, the primary challenges with these wild swine breeds are keeping them healthy and keeping them fenced affordably. Their powerful snout and rooting skills enable them to escape if they are not properly fenced. Rather than being pastured, local pigs are typically tethered. They often compete for table scraps with pets, tend to be stunted with poor growth, and can also be stressed by parasites (Figure 3.2). Internationally, basic established guidelines exist for swine raised in dirt lots, and tethering is not recommended. The University of Florida recommends 25 square meters per native swine (Meyer, 1993).

In the Philippines, both the Negros Warty Pig (*Sus cebifrons negrinus*) and the Palawan Bearded Pig (*Sus ahoenobarbus*) have been crossed with modern breeds with some success, but documentation of feed conversion and weight gain is hard to come by. Wild boar farmers in the UK cross pure wild boar males with domestic pig sows (usually Tamworths) to produce an increase in litter size, from an average of 5 in fully wild animals to 9 in hybrids. Hybrid vigor will contribute to better feed conversion, and hybrid pigs may benefit from fermented feeds. However, even with better feed conversion, increased costs may not justify the added carcass weight.

The remainder of this article will discuss methods for and benefits of lowering feed costs for modern pig breeds that tend to gain weight quickly and that are kept in a managed environment on cement or sawdust bedding. At the Aloha House, we have been using the "no-wash" happy pig protocol, as promoted through various Natural Farming networks. A complete description of the system is discussed in my book. In this system, hogs are kept on a 1-meter deep sawdust bed and EM is added to the feed and water daily and sprayed weekly on bedding. Even sows enjoy farrowing on the deep beds and fermented feeds (Figures 3.3 & 3.4).

(Top to Bottom) ***Figure 3.2:*** *Tethered wild hogs like the Sus ahoenobarbus (Palawan Bearded Pig) in Palawan, Philippines, rarely thrive under domestic conditions.* ***Figure 3.3:*** *Happy Pigs on EM inoculated sawdust bedding.* ***Figure 3.4:*** *Farrowing is accomplished on high quality farm derived feeds and the addition of finely crushed livestock lime.*

Feed Sources

Many quality feed ingredients are available in most countries. Make sure you locate the best quality possible. Also, note that many feed programs in the industrial paradigm are not viable or profitable in developing countries!

Choosing High-Quality Inputs

Corn-fed pork is a phenomenon that came about through a glut of low-cost maize production in industrialized countries. Modern corn has a higher carbohydrate level and a corresponding lower level of protein. By contrast, rice bran has twice the crude protein of corn, and is often less expensive. In a natural feed system, protein is the number one limiting factor in performance and growth of livestock; it is also the most expensive to purchase. If you keep the target protein level appropriate for the age of the animal, everything else will balance out with your natural feed. In creating your pig feed, you pay for protein. Old corn-based feed formulas are based on corn varieties that had more protein than the modern dent corn that permeates our supply chain (which also contains glyphosate residues and is often genetically modified). On Palawan, where Aloha House is located, corn is approximately twice the price and contains half the protein of rice bran, making corn protein four times more expensive than rice protein. We want natural feed supplies for our hogs to be economical and to assure the best end product.

Unique Uses of Crops and Crop Residues Around the World

Innovative feeding solutions are found in various countries. Peanut tops, corn stalks, cabbage waste, and banana stalks are examples of useful agricultural byproducts used in the Philippines for hog feed production. Dried cassava is also used in Mindanao and Luzon islands. In Palawan, the large singular leaf of a wild aroid called *Amorphophallus paeoniifolius* is harvested from the understory of wetland forests and sliced or chopped for feed (Figure 3.5). In India, varieties of these aroids (called elephant foot yams) are grown for their edible tubers.

In Thailand, banana stalks are fermented for pig feed. Fresh sliced or shredded banana stalks are mixed with sugar and rock salt (at a ratio of 100 kg chopped stalks : 4 kg sugar : 1 kg rock salt) and fermented for three days in a bucket. Various naturally-occurring cultured microorganisms are added to enhance the fermentation process. After three days, the fermented produce is mixed with an equal amount by weight of high-protein brans and fish meal (Tancho, 2015). *[Eds.' Note: For further reference and details on these natural farming pig feed recipes, please see Dr. Arnat Tancho's "Natural Farming" and "Natural Farming Cartoon" books, which are available in English and many other southeast Asian languages at the ECHO Asia Office.]*

In Kenya, sweet potato vines are a valuable byproduct for livestock. Vines are chopped and fermented with EM1. Addi-

Figure 3.5: *Amorphophallus palawanasis - Elephant foot yam in Palawan, Philippines.*

tional corn meal and protein are added to enhance performance (The Organic Farmer, 2015).

Cut and Carry Legumes and Grasses

Grasses can be an important forage source for animals. According to Dr. Martin "about 75% of forage consumed in the tropics is grass" (Martin, 1993). At the Aloha House, we grow a biodiverse spectrum of fodder crops that we bring to our hogs as cut and carry (Figure 3.6; Table 3.1). Compared to rooting livestock, people are better able to harvest carefully and leave plants intact. We grow Vetiver (*Chrysopogon zizanioides*) for slope stabilization and swale management in our water harvesting system. We also use it as a forage; we can harvest the young Vetiver with some frequency during the rainy season and maintain forage nutritional value. We have also utilized fresh cut *Pennisetum purpureum* (Napier) as a forage for hogs and cattle.

Figure 3.6: *Cut & Carry - readily consuming young vetiver grass.*

Table 3.1: *Potential of cut and carry grasses - Chrysopogon zizanioides (vetiver) (Wikipedia).*

	Young Vetiver	Mature Vetiver	Old Vetiver
Energy [kcal/kg]	522	706	969
Digestibility [%]	51	50	-
Protein [%}	13.1	7.93	6.66
Fat [%]	3.05	1.30	1.40

At the Aloha House, we have utilized the Sloping Agricultural Land Technology (SALT) system since 2001. This system uses legume tree and shrub perennials to stabilize soil along hillside contours, also incorporating annual alley crops. The fermentable legumes are important sources of protein and vitamins, as well as enzymes that boost feed digestibility (Watson, 1985). Over the years, we have been able to save seed from these prolific producers and expand from our starting stocks. We have established stands and contours of Ticktrefoil (*Desmodium rensonii*), Malabalatong (*Flemingia congesta*), *Indigofera*, Kakawate or Madre de Cacao (*Gliricidia sepium*), Ipil-Ipil (*Leucaena leucocephala*), and *Mangium acacia*. All of these legume species are valuable for fermented feeds (Agroforestry.org, 2008).

Fermenting Greens

Crop residues can be used to lower feed costs. At Aloha House, legumes such as peanut tops, *Gliricidia sepium*, *Leucaena leucocephala*, *Flemingia congesta*, *Desmodium rensonii*, and *Pueraria lobata* (Kudzu) have been used successfully. Moringa and floating ferns are also used. Within the Korean Natural Farming (KNF) network, certain additives are avoided in hog feed due to alleged detrimental effects. We apply the KNF hog system at Aloha House, and therefore do not use bean vines or cassava leaves because of reports of bad side effects. The side effects are not well documented, but we avoid these as a precaution, and we have many alternatives. The protocol for introducing a new ingredient in a formula is to go slow and add one new ingredient at a time, to be able to tell which ingredient is having what effect. Be on guard for ill effects. Track weight gain and compare with normal growth. If scouring (diarrhea) occurs, remove the experimental ingredient and return to proven feed components.

Sourcing Mill By-products

To create a successful feed mix for your hogs, you must properly source high quality inputs, most often from local mills. “D1” rice bran (explained in more detail below) is considered the premium grade for livestock. Other lesser grades (D2 to D4) should be avoided, because protein content is lower and the percent of indigestible fibers (i.e. cellulose) is higher. 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. Top quality rice bran is 12% to 14% crude protein, while most modern corn varieties contain only half this amount of crude protein.

Copra meal is the by-product of coconut fat extraction and can be obtained at oil mills. Copra meal contains up to 24% crude protein, but it should be limited to 10% of your formula by weight. It contains good quality protein but also a high amount of fat (similar to Black Soldier Fly larvae). Too much fat in the diet can cause scouring (diarrhea), and it will also sacrifice weight gain by reducing consumption of carbohydrates and protein. Copra meal is still worth including in our formula

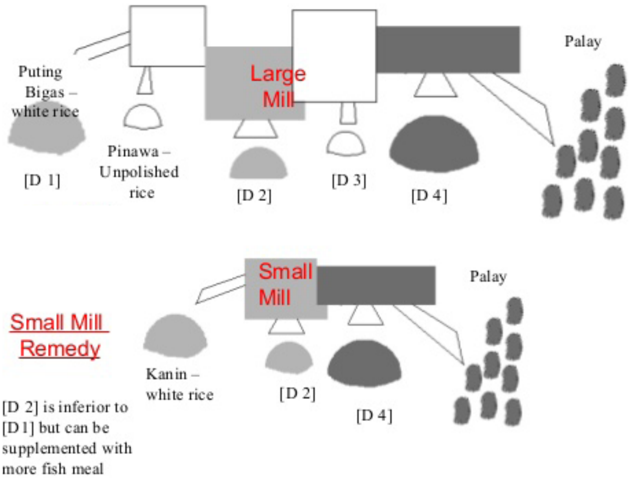

Figure 3.7: *Rice mill primer (Mikkleson, 2005).*

at 10% maximum by weight, because in our area it has a favorable price point. Fermentation (discussed below) further boosts digestible protein of copra meal. If copra meal is not available, increase the amount of fish meal used.

Rice Mill Challenges

Large Cono Mills are able to produce highly polished rice (often labeled "WMR" for Well Milled Rice), leaving a waste byproduct that is valuable for feed formulation (Figure 3.7). Compared with other rice byproducts, this D1 rice bran has the highest vitamin, mineral and protein content.

In many areas, only small mills (sometimes called "Satake Mills") are available. These mills do not highly polish their rice, and may label it "RMR" (Regular Milled Rice). Satake Mills produce only D2 rice bran; it is inferior to D1 bran, but can be used in the Aloha House formula if it is supplemented at an increased rate of 25% more fishmeal than the basic formula by weight.

Floating Ferns

Many floating ferns and aquatic plants are high in protein. Aquatic plants can grow well in ponds that have adequate fertility to support them. They can be utilized for hog feed and are excellent as a cost-saving supplement when expensive purchased feeds are used. Floating ferns such as *Azolla* spp., duckweed (various genera and species), and even *Salvinia* spp. can be utilized if they are cultured and harvested efficiently (Figure 3.8). Omnivores such as swine and poultry readily eat large quantities of these greens as a feed source. Options for production include separate dedicated ponds, containers or troughs, and 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 over-graze and deplete the crop! In addition, if one goal of the pond is algae production, plants growing on the surface will block sunlight

Figure 3.8: *Azolla and salvinia production at Aloha House.*

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.

In experimental trials in India that compared duckweed (*Lemna minor*), kang kong or morning glory (*Ipomoea reptans*), water caltrap (*Trapa natans*), and *Salvinia cucullata* (often mistaken for Azolla), both duckweed and morning glory had good feed conversion ratios and high protein: 28% and 32% respectively (Kalita, 2007). Both of these can be great fodder crops. 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.

Be careful not to overharvest these crops, or production will not be sustainable. As a general rule of thumb (under ideal conditions), you should 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 the plant in the rapid vegetative stage, so you will have to monitor which method of harvest is more productive in your system. Azolla tolerates moving water better than duckweed. Salvinia grows the fastest, but can be very invasive.

Pelletized Feeds

If you seek to intensify hog production, use of concentrated feeds is worth considering. However, commercial feeds are very expensive. The ECHO Technical Note #64 on fish farming (Murnyak, 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). Pelletized feeds are not necessary, despite marketers that portray pellets as more “modern” or “scientific.” The added cost of management and labor to make pelletized feeds outweigh the gains in growth. Hogs will readily consume a mash or crumbled fermented feed with great interest.

Documented Problems with Soy and GMO Crops

Aloha House is a soybean-free operation due to the detrimental health effects of soy. The phytoestrogens and enzyme inhibitors of soy are problematic for both livestock and humans. Concerns documented with soy include the following:

High levels of phytic acid in soy reduce a body’s assimilation of calcium, magnesium, copper, iron, and zinc. Phytic acid in soy is not neutralized by traditional preparation methods such as soaking, sprouting, and long, slow cooking. Diets high in phytic acid have caused growth problems in children.

Trypsin inhibitors in soy interfere with protein digestion and may cause pancreatic disorders. In test animals, consumption of soy containing trypsin inhibitors resulted in stunted growth.

Soy phytoestrogens (i.e. plant estrogens) disrupt endocrine function, and can potentially cause infertility and promote breast cancer in adult women.

Soy phytoestrogens are potent anti-thyroid agents that cause hypothyroidism and may cause thyroid cancer. In infants, consumption of soy formula has been linked to autoimmune thyroid disease.

Vitamin B12 analogs in soy are not absorbed, and actually increase the body's requirement for B12. (Nienhiser, 2003)

GMOs (genetically modified organisms) are also potentially problematic. A recent study linked cancer in hogs to their consumption of GMO soy and maize (Carman, n.d.). With so many other crops to choose from, we have chosen to avoid GMOs at the Aloha House. *[Eds.' Note: See the "Soy References" section for more information.]*

On-Farm Production of Hog Feed & Formulas

With experimentation and careful recordkeeping, hog farmers can produce their own high-quality feed. In many countries, farmers can purchase readily available ingredients for production of cost-saving feeds. However, farm-generated ingredients make hog feed even more economical! At Aloha House, two people can produce 200 kg of moist feed in less than an hour.

Benefits of Fermentation

The fermenting activity of certain beneficial microorganisms during the production process can enhance digestibility and shelf life of hog feeds. According to one study, the use of microorganisms increased the crude protein in copra meal from 17.24% to 31.22%. The amino acid profile was also found to be greatly improved (Cruz, 1997).

When fermenting your feed, be sure to use proven strains that are not cross-contaminated with wild pathogens. We use EM-1, a commercial product that undergoes laboratory testing and is approved for livestock and aquaculture by the Department of Agriculture and 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. Thailand now consumes more EM-1 than Japan.

EM-1 contains cultures of robust lactobacilli, photosynthetic bacteria, beneficial yeast, and more. The microorganisms feed on sugars and other carbohydrates, while creating secondary metabolites that increase the nutrient range of the feed. The probiotic value is very high. 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 at ECHOcommunity.org.

If EM-1 is not available, try using cheese whey or yogurt whey, sourced from a local creamery. Start small by substituting the whey at the same rate as EM-1 in the formula below, and add more in subsequent batches if it did not have an effect. Good fermentation should create a sweet and sour smell after two weeks (Figure 3.9). If foul odors such as rotten eggs (sulfides) or black molds occur, do not feed it to your hogs. Instead, add your small failed experimental batch to the compost heap and use it as fertilizer.

Another alternative to EM-1 is to use indigenous microorganisms (IMOs). In the KNF (Korean Natural Farming) system, "materials are mixed with sugar, salt, and IMO solution." *[Eds.' Note: For more information on the creation and use of IMOs, please see the presentation "An Introduction to Asian Natural Farming" on ECHOcommunity.org]*

Beginning Formula for Hog Starter Feed

Table 3.2 is a good recipe starting point for creating your own hog starter feed. Be sure to keep notes and adjust the ingredients based on your available feed-

Figure 3.9: *Filippino farmers packing inoculated EM feed into airtight food grade containers. It will be ready after it ferments for two weeks.*

Table 3.2: *Hog starter feed cost comparison and on farm feed inputs (weaning to 18 kg.) (Philippine Council for Agriculture, 2000).*

Hog Feed with Fish Meal & High Crude Protein Greens						
	Crude Protein	Cost USD / 50 kg Sack				Cost USD/kg
Commercial Feed	18.00%	35.00				0.70
Fermented EM Feed	18.02%	16.21				0.32
Ingredients	Crude Protein	Weight (kg)	%	Cost USD/kg	Crude Protein Units	Cost USD/input by % of feed
D1 Rice Bran	14%	50.00	71.2	0.30	7.00	15.00
Copra Meal	22%	7.50	10.7	0.23	1.65	1.73
Fish Meal	47%	6.00	8.5	0.95	2.82	5.70
Floating Ferns/Legumes	15%	4.00	5.7	0.00	0.60	0.00
Livestock Lime	0%	0.10	0.2	0.20	0.00	0.02
Rock Dust Minerals	0%	0.20	0.3	0.05	0.00	0.01
Charcoal - Fine	0%	0.20	0.3	0.03	0.00	0.01
Fish Silage (FAA)	29%	2.00	2.8	0.15	0.58	0.30
EM & Molasses	100 ml ea.	0.20	0.3	0.20	0.00	0.04
Total		70.20	100%		12.65	22.81

**"Crude Protein Units" refers to the crude protein (%) in kilograms (item weight x CP%)*

stock and the performance of your farm-made feeds! Costs listed are relevant for our location and might differ elsewhere.

Mixing Sequence and Moisture Content

Make sure you have a clean, smooth concrete surface for mixing your feeds. When we ferment hog feed, first we pre-mix all our dry materials (rice bran, copra meal, etc.). Then we mix in the greens (e.g. salvinia, azolla, and legumes) and crop residues, so that the dry material coats the moist greens. Next we add 100 ml. each of EM-1 and molasses, diluted in 10 liters of water. We want the moisture content of the mixture to be between 30 and 50%; you may need to add additional water to reach this target moisture range.

A simple field test for moisture content in the 30-50% range is the "Ball Test." Take a portion of the feed in two hands and form a ball with mild pressure. If it sticks together without dripping, it is in the target range. Congratulations! If the ball does not stick together, the mixture is too dry. Carefully add water a little at a time and test again. If it is dripping wet, it is over the moisture target range and you need to add additional formula-balanced dry materials to lessen moisture. Do not just add rice bran as a drying agent because you will compromise the recipe and it will not perform well.

After completely mixing all ingredients to 30-50% moisture content, we compress it in airtight pails and ferment for two weeks (Figure 9, page 46). This will ensure more uniform moisture content of the materials and achieve a better end product than a fresh feed mix.

Formulas for Modern Hogs

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 hogs on the current feed system (as an experimental control) so you have something with which to compare. After one month, compare the weight of hogs with your new feed and with the control.

We encourage you to use ingredients that are available in your area. Learn to optimize your own blend based on regular testing. A spreadsheet is useful for adjusting inputs and formulating feeds. After many months of record keeping, you will be able to evaluate the benefits of your farm-generated feeds. Crude protein is a good starting point; we find that if we formulate our mix based on crude protein, the rest takes care of itself.

Earlier I discussed floating ferns and their use as a fresh feed or for fermenting. Floating ferns are good for biodiversity and can create a broader range of inputs. You can use a combination of duckweed, azolla, and salvinia as a component of your low-cost, high-quality hog feed. Learn to culture these ingredients. Purchasing them is very expensive! Spirulina (a cyanobacterium, also known as blue-green algae) is a possible alternative to floating ferns. Over 30% of worldwide spirulina production goes to non-human feed stuffs (Belay, 1996). Other substitutions have been explored with mixed results, including water hyacinth in Nigeria (Igbinosun, 1988). I have not experimented with water hyacinth and would not recommend it due to its poor results in this study, but if you do, please send us your results!

Vitamins and Minerals

Finely crushed rock powder from gravel mills will have a range of minerals to supplement any deficiencies in cut greens or floating ferns (Murnyak, 2010). If we do not have rock powder, we add our organically grown moringa at 1% by weight of the mixture. Finely ground livestock-grade limestone from an agricultural supplier of feed store can also be added for bone growth support and lactating sows.

Hog Feeding Schedule and Protein Adjustments

Protein is the expensive part of an intensive feed operation, and you should not use more than you need. If fresh greens are not used as cut and carry, then follow a protein reduction schedule based on the developmental stage of the hog in order to use less of the more expensive feed (Table 3.2, page 51). We follow well-established swine nutrition guidelines from the University of Missouri (Rea, 1993). Hogs need different amounts of protein depending on their stage of growth. To minimize costs, be sure to remove your most expen-

Table 3.3: *Schedule for using fermented feed with crop residues ("Ad lib" means that feed is continually available to the pig). (Source: http://www.slideshare.net/mik1999/sustainable-livestock-1-cattle-and-hogs)*

Feeding for Developmental Stages			
Period	**EM Fermented Feed**	**Crop Residue Cut and Carry**	**Daily Amount of EM Feed**
0 to 45 days (to weaning)	Pre Starter	None	Ad Lib (continual until 5 pm)
46 days to 18 Kilos	Starter	12:00 noon	Ad Lib (continual until 5 pm)
18-50 Kilos	Grower	3 x daily	1-2+ Kilos EM Feed
50+ Kilos	Finisher	Ad Lib	1 Kilo
Sow	Maintenance	3x	2-3 Kilo
Sow	Pregnant	Ad Lib	3 Kilo
Sow	Lactating	Ad Lib	3 Kilo - 1/2 kilo/ piglet

sive protein as levels are adjusted. In our case, fishmeal costs the most and is what we would reduce based on our animals' developmental requirements. Starter feed (Table 3.2, page 51) is used from weaning to 18 kg, and contains 18% protein. This high protein feed prevents stunting in the early stages. Protein is reduced to 16% for hogs in the "Grower Stage" (18-50 kg); we reduce fishmeal by three kg in this stage. To further economize production, hogs in the "Finishing Stage" (50 kg. to harvest) require only 14% crude protein. Finisher feed can be adjusted by reducing fishmeal by two more kg in our formula. All other ingredients remain the same. Greater savings and better animal health can be obtained with on-farm production of fermented hog feed, compared to commercial feed (Table 3.2, page 51).

At Aloha House we choose to maintain the starter ration throughout the life of our hogs and reduce overall protein by increasing the amount of vegetative feed that we offer. Table 3.3 (page 53) outlines the schedule for developmental stages of swine used on our farm. Weaners do not participate in cut and carry. As hogs mature, they are fed more "free food" from the farm in the form of crop residue and cut and carry.

Conclusion

Small-scale hog feed production can be managed by the careful use of locally grown and farm-generated inputs. Planning production two weeks in advance will assure a steady supply of nutritious fermented feeds. If you supply yourself with high quality inputs through efficient production and harvesting, and produce your own feeds, you will have more profits due to less capital input.

Fermented Banana Stalk silage at the ECHO Asia Small Farm Resource Center.

“Chicken Salad” at the EM Farm, Saraburi, Thailand.

Chapter 4:

Integrating Poultry into the Smallholder Farm and the Creation of Poultry Feed

Introduction

Farm-generated fertility contributes to a more sustainable agricultural system. Crop residues and manures are part of the nutrient cycle for plant production and can lower input costs through the use of thermophilic composting, vermiculture, bokashi production, and/or green manures. Farm-generated feeds can also reduce expenses, as farmers manage and utilize resources already available to them. Chickens in particular can be very expensive to feed on a small scale with purchased commercial feeds. In this ECHO Asia Note, we will explore a variety of alternatives for small flock feeds.

Chicken feed ingredients vary from area to area throughout the world. Selection is usually based on availability, quality, and cost. While the use of some materials are based on scientific principles, like crude versus digestible protein, the nutritional benefits of many of these materials are not well researched or proven. Chickens are omnivores and do well on pasture, in confinement, or even ranging freely in forest environments. In this article, I will share ways to maximize farm-generated feeds for chickens that are pasture-raised, utilizing as many natural feed options as are appropriate for your circumstances. Later in this article I will describe how to intensify the feed ration, in case you only have a small exercise yard for your birds or they are confined and caged.

Figure 4.1: *Happy Aloha House chickens.*

Pasture

Pasture can be anything from thick lush legume and grass polycultures to weedy scrub brush fields. Get your birds out in the sunshine; this is a great way to boost vitamin D for chickens' health and improve the nutrient density of the eggs and meat. We don't want "feed lot livestock" or confined chickens that are deprived of sunshine and living in the dark (Figure 4.1)!

One challenge of a natural, foraged diet in Southeast Asia is protecting poultry from predators. Pasture or forest can be rich in insect protein and forage, but it comes with the risk of predation and even theft. The chicken tractor is one way to protect your investment. It is a movable cage built for small flocks: our 1.2 m x 3 m tractor stocks 10 to 15 meat birds, or half as many layers. The chicken tractor has a water supply and feed tray. We move it once or twice a day, depending on stocking density and bird size. It is light enough to be moved by one person (Figure 4.2). We found wheels to be problematic on our rugged Palawan terrain, and designed the "Aloha Chicken Sled" as an alternative to wheel-based units (Figure 4.3).

When moving a chicken tractor, be careful to push the rig from behind, to prevent running the chickens over. Chickens tend to flee away when they are disturbed, so if you pull from the front they will run to the back and may get injured.

On a larger scale, a movable solar electric feather net can be used to keep predators out. "The live foods they [chickens] forage—green growing plants, wild seeds, earthworms, slugs, and insects—are of a quality we cannot hope to match with anything from a bag," writes Harvey Ussery in "Managing Poultry on Pasture with Electronet" (Ussery 2005). Perhaps you are curious if you can modify an electric fence meant for cattle, to use it for chickens. At the Aloha House, we have a solar charger built into a control unit with battery to electrify our cattle fence, which we use to manage planned grazing for cattle. The fencing is livestock-specific, so make sure yours is specific for poultry; we do not recommend cattle fencing for poultry. Instead, we recommend using the feather net or "Electronet," designed specifically for poultry.

If you are unable to manage electrical technology in your area, you should at least ensure that your birds have access to a scratch yard: a small, fenced-in, predator-proof area with a good dose of sunshine! A scratch yard can be improved with the addition of cut greens, crop waste from your garden, and/or various grasses. I have friends in Dubai that use grass cuttings as a feed supplement as well as for bedding. Be resourceful and you can find many "waste" streams that may be appropriate for your flock feed!

A larger space for chickens to forage is even better. In the Philippines, we plant mongo bean (Mung bean or *Vigna radiata* - available from the ECHO Asia Seed Bank) on alternate rotating pastures for our layers. We try to time it as a fodder crop and let it get to flowering stage then let the chickens devour it before beans are formed. If you want to grow and harvest the beans you can, but the forage nutrition will be less than in the flowering stages. When one area is depleted, it is closed down and replanted while the chickens are transferred to the next area for foraging. I recommend three pastures or more if you have the room.

Figure 4.2: *The Aloha Chicken Sled is light enough to be moved by one person.*

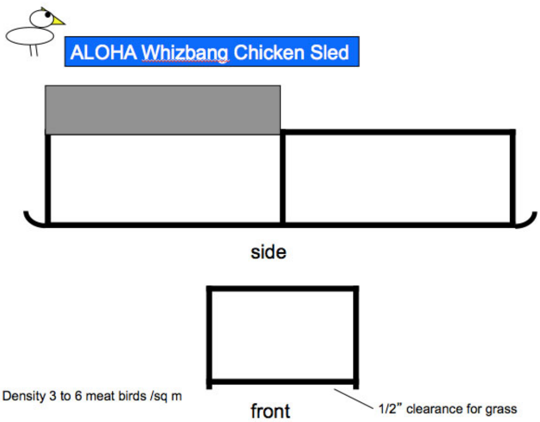

Figure 4.3: *The Aloha Chicken Sled is our alternative design without wheels.*

Figure 4.4: *Examples of scratch available in a local Palawan market.*

Scratch

You can supplement your poultry's grazing diet by distributing grains into the bedding, exercise yard, or pasture. Most farmers have a special call to alert their birds to this supplemental feed that is thrown out into the grass or dispersed into a deep litter bed (to enhance aeration as the chickens search for the grains). Supplementing like this stimulates the chickens to forage and encourages them to move out to areas they may not have yet exploited. It also enables the farmer to take inventory and do a head count.

Cracked corn is a preferred supplemental feed in most areas, but is not always cost effective. In fact, many different beans, seeds, and grains can enhance the growth and performance of your birds. This list is not exhaustive, but wherever chickens are raised around the world, farmers have tried a large variety of supplements: cracked corn, pili nuts, mongo beans, kidney beans, peanuts, etc (Figure 4.4). When selecting scratch feeds, locate supplements that disperse well by hand, are locally available, and are cost-effective.

Benefits of Grass-Fed Livestock

The cheapest, and certainly the easiest, ways to feed livestock are to provide them with access to pasture or to provide them with greens through a cut-and-carry system. Various protein sources from around the farm like azolla or black soldier fly (BSF) larva can be used to augment pasture and greens.

Grass-fed livestock offers plenty of nutritional benefits that include:

- More fat-soluble vitamins (A, D, E, K) in the fat.
- Higher Conjugated Linoleic Acid (CLA), an anti-cancer and weight loss compound, in the fat.
- More minerals - mostly in the fat.

With fewer grains and more greens, along with insects, fish, coconut meal, etc., the ratio of omega 3 and omega 6 fatty acids in grass-fed poultry is more in-line with traditional diets and much more healthful for consumers than consumption of modern poultry. Feedlot grain-fed livestock have high levels of omega 6 fatty acids. Instead of adding omega 3 fatty acids to the chicken diet, reduce the omega 6 fatty acids by reducing grain and use insects and fish meal for balanced nutrition. Dr. Weston Price found a near-equal ratio of omega 3:6 fatty acids in human diets, not totaling more than 5-6% of fat intake by calories, to be optimum (Figure 4.5) (Fallon *et al*. 2000). For meat, egg, and fat quality to be balanced for human consumption and poultry health, we want that balance of omega 3 and 6 fatty acids in the feed.

On-Farm Production of Chicken Feed, Including Formulas

With experimentation and careful record-keeping, chicken farmers can produce their own high-quality feed. In many countries, farmers can purchase readily available ingredients to produce cost-saving feeds. However, farm-generated ingredients make chicken feed even more economical! At our farm, two people can produce 200 kg of moist feed in less than an hour. Many items can potentially be used to produce a balanced ration. The best advice I can give is to be flexible depending on your context and what is cheaply (or freely!) available. Keep your options open and do some research! Below I describe some of the options available in Southeast Asia.

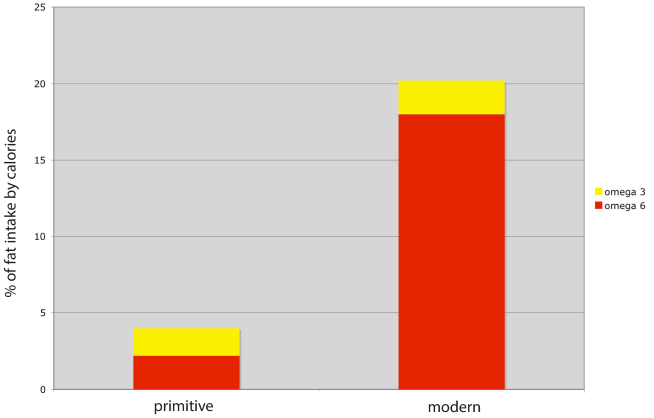

Figure 4.5: *"Essential Fatty Acids in Primitive and Modern Diets," by Sally Fallon Morrell. Source: Weston A. Price Foundation, "Traditional Diets and the Oiling of America" series "Traditional Diets III" presentation.*

Floating Ferns and Duckweed as an Alternative Feed

Many floating ferns and aquatic plants are high in protein. Aquatic plants can grow well in ponds that have adequate fertility to support them. They can be utilized for chicken feed and are excel-

Figure 4.6: *Azolla and salvinia production at Aloha House.*

lent as a cost-saving supplement when expensive purchased feeds are used. Floating ferns such as *Azolla* spp. and *Salvinia* spp. can be utilized if they are cultured and harvested efficiently (Figure 4.6, page 61). Duckweed (various genera and species) can also be used. Swine and poultry (both omnivores) readily eat large quantities of these greens as a feed source. Options for production include net-protected rafts within a fish culture, or separate dedicated ponds, containers or troughs. Remember, any fodder crops grown within a fishpond must be protected or isolated from the fish, otherwise the fish will over-graze and deplete the crop. In Figure 4.6, fish are kept in a separate tank and azolla is growing from the pumped nutrients and water and returned to the fish cleaned and oxygenated. *[Eds.' Note: For more information on using floating ferns and duckweed for fish food and hog feed, refer to chapters 2 and 3.]*

Experimental trials have been done in India, comparing *Lemna minor* (common duckweed), *Ipomoea reptans* (kang kong or morning glory), *Trapa natans* (water caltrap), and *Salvinia cucullata* (often mistaken for azolla). Both duckweed and morning glory had good feed conversion ratios and high protein: 28% and 32% respectively (Kalita, 2007). Both of these can be great fodder crops. I wish that azolla (*Azolla caroliniana*) had been included in the India study; it is another fast-growing floating fern, and has a reported protein range of 19-30%.

Be careful not to overharvest floating ferns and other aquatic plants, or production will not be sustainable. As a general rule of thumb (under ideal conditions), you should harvest no more than half of the floating biomass per week (or $1/7^{th}$ of the total biomass per day). The trick is to keep the plant in a rapid vegetative stage. To do this, you will have to monitor which method of harvest is the most productive in your system. Azolla tolerates moving water better than duckweed. Salvinia grows the fastest, but can be very invasive. Our one-year study measuring azolla yields in aquaponic conditions showed yields ranging from 310 grams to 490 grams per day, depending on various factors.

Auto-Harvesting Black Soldier Fly (*Hermetia illucens*) Grub Culture

Kitchen waste or manures can be utilized for black soldier fly (BSF) (*Hermetia illucens*) grub production, to supplement the natural diet of your chickens. BSF larvae are very nutritious and can be grown economically on waste. Actively feeding grubs will secrete a natural fly repellant called a synomone (a substance used for interspecies chemical communication) that alerts and warns other kinds of flies to stay away from the food, as BSF are already present. Numerous designs for auto-harvesting BSF devices are available online. These act as containers for grub production; when properly managed the mature grubs migrate from the container on a 35º incline and are dropped into a holding container, directly into a fish pond, or into a chicken coop (Figures 4.7 & 4.8).

Benefits of Fermentation in On-Farm Feed Production

The fermenting activity of certain beneficial microorganisms during the production process can enhance the digestibility and shelf life of chicken feeds. According to one study, the use of microorganisms increased the crude protein in copra meal from 17.24% to 31.22%. An amino acid was also found to be greatly improved in quantity (Cruz, 1997).

Please note that not all flocks like a wet feed. You can mix feed without fermenting in the morning and use it immediately if your chickens do not appreciate fermented feeds, which tend to be wet. In addition to chicken feed, you can also ferment your feed for hogs, ducks, and fish with the help of diverse probiotic groups of microbes. However, we do not recommend fermentation for ruminant feeds (refer to chapter 5).

Figure 4.7: *Images of the Black Soldier Fly (BSF) device used at Aloha House.*

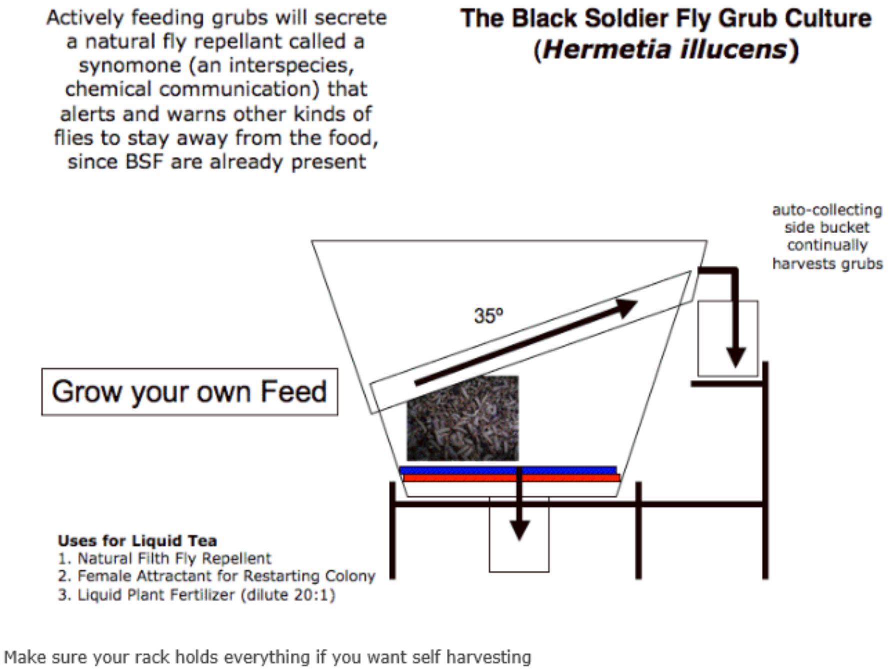

Figure 4.8: *Diagram of the Black Soldier Fly device used at Aloha House.*

When fermenting feed, be sure to use proven strains of probiotic groups of bacteria, yeasts, and microbes that are not cross-contaminated with wild pathogens. At the Aloha House, we use EM-1, a commercial product that undergoes laboratory testing and is approved for livestock and aquaculture by the Department of Agriculture and the Bureau of Fisheries and Aquatic Resources in the Philippines. EM-1 was formulated by Dr. Teruo Higa in Ryukyus University, Okinawa, Japan, and it is readily available in over 100 countries. Thailand now consumes more EM-1 than Japan!

EM-1 contains cultures of robust lacto-bacilli, photosynthetic bacteria, beneficial yeast, and more. The microorganisms feed on sugars and other carbohydrates while creating secondary metabolites that increase the nutrient range of the feed. The probiotic value is very high. If you would like to learn more about using EM-1, 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 on ECHOcommunity.org or can be purchased in hard copy at the ECHO Asia office.

If EM-1 is not available, try using cheese whey or yogurt whey, sourced from a local creamery. Start small by substituting the whey at the same rate as EM-1 in the formula below, and add more in subsequent batches if it does not have an effect. Good fermentation should create a sweet and sour smell after two weeks. If a foul "rotten egg" odor (from sulfides) or black mold occurs, do not feed it to your chickens. Instead, add your small failed experimental batch to the compost heap and use it as fertilizer.

Another alternative to EM-1 is to use indigenous microorganisms (IMOs). In the Korean Natural Farming (KNF) system, materials are mixed with sugar, salt, and IMO solution.

Fishmeal is a good source of protein. Marine fishmeal and tilapia meal have been used in various settings with good results. The use of fishmeal is typically restricted to 5-10% of poultry diets. We use more than that in our chicken ration. Our natural flock management includes pasture, greens, scratch, feeds, and free choice minerals; with lots of choice available, the birds are able to select and balance their diet themselves, naturally adjusting or compensating to get the right amounts of nutrients. Please note that fishmeal can vary considerably in quality and can potentially be a source of Salmonella contamination when included in poultry diets. Also, high levels of fishmeal in poultry diets can result in fishy-tasting meat and eggs (Ponce *et al*., 2002).

Documented Problems with Soy and GMO Crops

Aloha House is a soybean-free operation due to the detrimental health effects of soy. The phytoestrogens and enzyme inhibitors of unfermented soy are problematic for both livestock and humans. Documented concerns with soy include the following:

High levels of phytic acid in soy reduces a body's assimilation of calcium, magnesium, copper, iron, and zinc *[Eds.' Note: Please see EDN #103 "Phosophorus (and other) Deficiencies in a Diet High in Phosphorus," to learn more about the problem with phytic acid].*

Phytic acid in soy is not neutralized by traditional preparation methods such as soaking, sprouting, and long, slow cooking.

Diets high in phytic acid have caused growth problems in children.

Trypsin inhibitors in soy interfere with protein digestion and may cause pancreatic disorders. In test animals, consumption of soy containing trypsin inhibitors resulted in stunted growth.

Soy phytoestrogens (i.e. plant estrogens) disrupt endocrine function, and can potentially cause infertility and promote breast cancer in adult women.

Soy phytoestrogens are potent anti-thyroid agents that cause hypothyroidism and may cause thyroid cancer. In infants, consumption of soy formula has been linked to auto-immune thyroid disease.

Vitamin B12 analogs in soy are not absorbed, and actually increase the body's requirement for B12 (Nienhiser 2003).

[Eds.' Note: See the "Soy References" section for more information.]

GMOs (genetically modified organisms) are also potentially problematic in animal feed. A recent study linked cancer in hogs to their consumption of GMO soy and maize (Carman *et al*. 2013). With so many other non-GMO crops to choose from, we have chosen to avoid GMOs at the Aloha House. The effects of feeding processed kidney bean meal (*Phaseolus vulgaris*) instead of soybean meal was linked to reduced egg quality of white leghorn hens (Hussein *et al*. 2015). Soy protein is cheap, but may not have the best amino acids for poultry growth compared to fish meal. Fish meal may be best because in evaluation of fishmeal protein supplementation to commercial feeds for egg layers and egg quality in warm tropical regions a study showed an important link to the usable amino acid profile of fishmeal (Omeke *et al*. 2013).

The Aloha Fermented EM Feed

Our all-around "Aloha Fermented EM Feed" contains 19% crude protein and costs 0.36 USD/kg here in Palawan, Philippines (Table 4.1). We have had good success feeding it to broilers and layers. The fine (<0.5mm) agricultural limestone included in the ration is important for bone development. Layers also need access to additional calcium, which will be discussed further in sections below.

The recipe in Table 4.1 (page 67) is a good starting point for creating a farm-derived poultry feed that saves time and recycles inputs. If you can manage a more complicated schedule for the protein demands of your flock as the birds develop, you can adjust your ration's protein by adjusting the quantity of fish meal.

Health Supplements Starting with Day-Old Chicks

You can increase the feeding capacity of chicks without using hormones by using natural health supplements that can also be created from on-farm inputs (Table 4.2, page 67). These supplements will give them better growth and development and increase their disease resistance. Details for each supplement are given.

Bamboo Leaves and Brown Rice Supplement

For day-old hatchlings, we finely chop bamboo leaves and mix with an equal amount of brown rice flour. Don't worry about depriving the birds—for the first day the chicks are "coasting" on the egg food and will not be set back by the high fiber. Rather, this treatment elongates their G.I. tracts and gives them extra feeding capacity. *[Eds.' Note: While feeding rice flour and chopped bamboo to day-old chicks is a common practice, it has not been scientifically studied.]* Most feed suppliers admit that "chicks don't need feed or water the first 48 hours after hatching" (Hamre, 2013).

Chopped Banana and Watermelon Supplement

Feed your chicks an equal amount of chopped banana and watermelon as an addition to other feed like rice bran or corn grits. Have it free choice - available at their own discretion and separate from your other feeds.

Herbal Water Supplement

Finely chop 100 grams of aloe vera and 100 grams of ginger, and mix with 100 grams of molasses and 100 ml of EM1. Ferment in 2 liters of water for 2 weeks. Filter this fermented solution and dilute 1:1 with water. Natural vinegar can be added at 1-3% by volume when you serve it to your chicks.

EMAS Water

"Effective Microorganisms Activated Solution" (EMAS) water helps to aid digestion by guiding the enzyme process. To make EMAS water, we dilute EM with 200 parts of water, to create a ratio of 1:200. We feed EMAS water on demand.

Table 4.1: *Aloha Fermented EM Feed for Poultry (Philippine Council for Agriculture, 2000).*

Poultry Feed with Fish Meal & High Crude Protein					
Fermented EM Feed Ingredients	Crude Protein	Weight (kg)	%	Cost USD/kg	Cost USD/input by % of feed
Rice Bran [D1]	14%	3.00	42.9	0.30	0.90
Copra Meal	22%	2.00	28.6	0.23	0.46
Fish Meal	44%	1.00	14.3	0.73	0.73
Corn Grits	7%	0.50	7.0	0.73	0.36
Fine (<0.5mm) Agricultural Limestone	0%	0.20	2.9	0.18	0.04
Rock Dust Minerals	0%	0.05	0.7	0.05	0.00
Sea Salt	0%	0.05	0.7	0.23	0.01
EM/Molasses 100ml	0%	0.20	2.9	0.18	0.04
Total		7.00			2.54
Cost USD/1kg					0.36

Table 4.2: *Health Supplements Program for Chicks*

Days	Particulars
1	Bamboo Leaves and Brown Rice Supplement
2-6	Chopped Banana and Watermelon Supplement
8-10	Herbal Water Supplement
11+	EMAS Water (EM diluted with 200 parts water)
18-20	Back to Herbal Water Supplement

Layer Strategies

At Aloha House, we always maintain a supply of grass, kang kong (morning glory), or other greens, to support layers' egg production. We practice a Thai-style feeding regime for our adult birds that we learned in Saraburi called "chicken salad". We add chopped greens (including azolla) on top of the morning feed ration (Figure 4.9). Layer chickens are large birds that are prone to exhaust their pasture and are often in need of additional greens. Serving your flock "chicken salad" provides them with a regular supply of nutrition beyond the fermented feed.

Our natural flock management includes the provision of greens, scratch, rationed feeds (fermented or mixed feed), and (starting at 18 weeks as indicated below) a free-choice source of calcium in the form of coarse, crushed limestone (1.5 mm – 3.5 mm). This means that we set out a diversity of options, including a source of calcium. It's important to note that layer hens typically lay eggs in the morning, and finish forming the egg shells as they sleep; they pull calcium from their digestive tract, mainly the gizzard. They require coarse agricultural lime or other calcium carbonates such as clamshells (1.5 mm – 3.5 mm). While a starting ratio of 70% coarse to 30% finely-powdered livestock lime (<0.5 mm) is recommended in a commercial feed; according to Leiterman, "A general rule of thumb is to have at least a 50:50 ratio of coarse to fine particle size calcium in the diet. Since layers eat very little during darkness, it is critically important for good eggshell development that there be adequate amounts of calcium still in the gizzard during the hours of darkness when the eggshells are being formed" (Leiterman 2013). The birds choose and balance their own diet from the selection of goodies that we provide at Aloha House. With the availability of the extra, coarse limestone, our egg production has almost doubled and we have seen increased eggshell quality and strength.

Figure 4.9 ***(left to right)*****:** *Preparing and feeding Aloha House birds "chicken salad".*

Figure 4.10: *Chickens and Muscovy ducks graze together at Aloha House.*

Ducks and Mixed Flocks

At Aloha House, we run Muscovy ducks on pasture with our chickens (Figure 4.10). They seem to forage differently, but do well together. We feed the ducks our basic feed ration but also provide a tub of water for hygiene so that they can clean themselves. Muskovy ducks are not big swimmers but do really well on grass! They also snatch flies out of the air. Local turkeys have also grazed well with our meat chickens, but the local Palawan Muscovy ducks we tried performed poorly in general. We will try again when we get a better breed!

Our meat ducks (Peking) and layer ducks (Malard) do better with a small pond of good quality water. We move the water through a grow area for plants with a small pump, in a closed-loop recirculating "duckponic" system. The plants use the nutrition in the water (from the duck feces), simultaneously cleaning it, while the ducks swim, aerate, and fertilize the plants with their waste that is deposited in the water. All of the plants grown in the system are used to feed hogs; they are not appropriate for human consumption. We include 'kang kong' (morning glory or *Ipomoea reptans*), water cress, azolla, and duckweed in our duckponic system.

Conclusion

Many poultry-raising options and feed sources exist in Southeast Asia. Thankfully, the costs of poultry production can be reduced by using a variety of alternative feed sources, many of which can be created on-farm or locally. Properly-fed, chickens, ducks, and turkeys are an important source of fat-soluble vitamins, protein, fats, and minerals for the human diet. At the Aloha House, we have had very good success with our natural flock management, which includes greens, scratch, rationed feeds, and free-choice calcium for poultry. We also provide access to pasture and plenty of sunshine. Together, these strategies will ensure profitable and high-quality production for your family and customers.

Aloha House's "Duckponic" system.

3 sisters at the Aloha Farm.

Chapter 5:
Integrating Ruminants into the Smallholder Farm and the Creation of Ruminant Feed

Introduction

The amazing multi-stomached ruminant comes in many forms, with varied nutritional requirements. Ruminants are even-toed, cloven-hoofed, four-legged, cud-chewing mammals of the suborder Ruminantia (within order Artiodactyla). Cattle, water buffalo, goats, and yaks are some of the ruminants found in Southeast Asia.

Ruminants are able to digest and extract nutrients from plant-based food by fermenting it in a specialized stomach with the aid of beneficial microorganisms, prior to digestion (Figure 5.1). After the initial fermentation, the fermented cud is regurgitated and chewed again. The process of re-chewing the cud (to further break down plant matter and to stimulate digestion) is called rumination. The waste from ruminants is valuable as a fertilizer for better production of the forage they eat. Manure should be used on the farm to maintain soil fertility. One of the benefits of

Figure 5.1*: A tethered cow wades in to graze on a barge of Gotu Kola and Salvania.*

integrated livestock will be better plant health and yield owing to the recycling of nutrients on the farm.

Many options are available for feeding ruminants on the small farm. Before selecting a feeding strategy for your situation, be sure that the benefits outweigh the disadvantages. Every farm is unique, and farmers must determine the most appropriate and cost-effective techniques for their needs.

Optimum Health of Ruminant Herds

Sunshine and grass are some of the best sources of nutrients for cattle and sheep, but may not provide a complete diet for other ruminants. However, all ruminants will benefit from some grassland when properly managed, perhaps integrated with other feedstocks, such as legume shrubs or even azolla. The bulk of this article will discuss two of the three topics listed in Table 5.1 (hay and natural pasture). We will not be covering silage or feedlot grains except to point out in Table 5.2 their advantages and disadvantages and with one reference below.

Cattle

Native beef and dairy cows in Southeast Asia are hardy breeds that thrive in a variety of environments from the high Himalayan mountains to the humid tropics. Some breeds were introduced by European settlers or migratory peoples. In the Philippines, the “native” cow was actually introduced by the Spanish; they brought several varieties to their newly claimed colony over 400 years ago. Many countries have old-line breeds that have cross-bred for centuries and that have adapted to the local climate and context. We will look at beef cattle feed options first and then suggest ways to increase milk yields for a dairy herd.

Water and Mineral Salt

Water must be available throughout the day to maintain herd health. Salt (sodium chloride, NaCl) is also an essential nutrient for cattle. On average, cattle should consume 11 to 15 grams of salt per day to meet nutritional requirements. Both sodium and chloride can be consumed by cattle in relatively high amounts without negative effects, but dietary levels of NaCl should not exceed 8 percent of the daily diet by weight (Ward and Lardy 2005). In areas where imported mineral blocks are too costly, sea salt can be given as “free choice” (i.e. salt is left out and animals are free to eat as much as they need). According to Troy Smith, the sodium in salt is the only mineral about which animals exhibit “nutritional wisdom”; he says they will take only as much as needed when offered free choice, without over-consuming (2008).

***Table 5.1**: Nutritive quality of hay, silage, and natural pasture in South Western Nigeria* (Ojo *et al.* 2013).

Treatment	CP	Ash	NDF	ADF	ADL	GV (ml/0.2 gDM)	C_g (ml/hr)	ME (MJ/kg DM)	OMD (%)	SCFA (µmol)
Hay	92.0 b	79.0 b	589.0 b	436.3 a	174.7 b	34.33 a	0.09	8.6 b	45.1 b	0.5 b
Silage	108.0 a	106.0 a	574.4 c	363.8 b	128.1 c	33.67 a	0.07	10.7 a	55.4 a	0.7 a
Natural pasture	59.0 c	71.0 c	705.2 a	440.6 a	184.4 a	13.67 b	0.08	5.3 c	32.8 c	0.2 c
±SEM	7.24	5.32	20.73	12.51	8.71	3.44	0.01	0.82	3.29	0.07

***Table 5.2:** Management, advantages, and disadvantages of various feeding strategies for ruminants.*

Feed Type	Management	Advantage	Disadvantage
Pasture	Moving animals	Access to rapidly growing green shoots	Overgrazing, parasites
Cut & Carry	Gathering greens and distributing them to animals	Legume trees can continually produce; free of parasites	Takes time to cut and carry; good forage species must be available
Hay	Gathering greens and distributing them to animals	Can be stored for drought/ snow fall	Can spoil; some waste occurs
Silage	Buying grains or gathering greens and fermenting them	Can be stored for drought/ snow fall	Can spoil; some waste occurs; may cause acidosis
Grain	Feed lot	Can be stored for drought/ snow fall	Can spoil; poor nutrition; can cause acidosis

Pasture Picker

Go Back

Pasture Species	Tolerance to				Minimum Rainfall (mm)	Clay?	Loam?	Sand?
	Frost	Drought	Water Logging	Heavy Grazing				
Couch, green (*Cynodon dactylon*)	P	P	P	VG	0	✓	✓	✓
Couch, Indian (*Bothriochloa pertusa*)	F	F	F	VG	600	✓	✓	✓
Elephant (*Pennisetum purpureum*)	F	G	F	P	850	✓	✓	✓
Guinea (*Panicum maximum*)	F	F	F	P	900	✓	✓	✗
Hamil (*see under Guinea Grass*)				P	0	✓	✗	✓
Humidicola (*Brachiaria humidicola*)	P	F	G	VG	1000	✓	✓	✓
Pangola (*Digitaria eriantha subsp. Eriantha*)	F	F	G	VG	1000	✓	✓	✓
Para (*Brachiaria mutica*)	P	P	VG	F	1000	✓	✓	✗
Plicatulum (*Paspalum plicatulum*)	F	G	G	F	800	✓	✓	✓
Signal (*Brachiaria decumbens*)	P	F	F	VG	1000	✓	✓	✓

P =poor, F =fair, G =good, VG =very good

Figure 5.2: *Pasture Picker pasture species guide. Available: https://www.tropicalgrasslands.asn.au/pastures/pasturepicker.htm.*

We make a stabilized rammed earth salt block that is still highly experimental. It consists of various quantities of on-farm red clay sub soil, 2 to 3 kilos jagged "plastering" sand, 100 to 500 grams molasses, 100 to 200 grams Epsom Salt, and 1 kilogram hydrated lime or Portland cement with 3 kilos sea salt. We are still analyzing the performance of these blocks, but they do have some research basis (Liu *et al.* 1995). Although many urea blocks are promoted, please note that our block is urea-free. There is a proven inability of the rumen microorganisms to synthesize sufficient quantities of all amino acids needed to prevent deficiencies or imbalances which may be a major factor responsible for the lowered animal performance obtained with urea diets (Chalupa 1968).

Pasture

Sustainable pasture development is possible with some advanced planning and the use of keen observation. The "Pasture Picker" is a good starting point to determine which tropical grasses are likely to succeed. The interactive "Pasture Picker" site is based on the book *A guide to Better Pastures for the Tropics and Subtropics* by L. R. Humphreys and I. J. Partridge (1995); it allows you to input your conditions to get the best recommendations (Figure 5.2). *[Editors' Note: please also see ECHO Asia Note #23 and chapter 3 about the potential of some of these fodder species to become weeds. When introducing new species to an area, please use caution and try them yourself first to ensure that the "solution" doesn't become another problem!]*

Cut and Carry Grasses and Legumes

The Aloha House grows a biodiverse spectrum of fodder crops that we bring to our goats and cows as "cut and carry." Humans are more adept than trampling livestock at carefully harvesting tall grass species, trees, and shrubs when they are at their prime. According to Martin (1993), "about 75% of forage consumed in the tropics is grass." Grasses can be gathered and fed to livestock if an efficient method is employed.

We grow Vetiver (*Chrysopogon zizanioides*) for slope stabilization and swale management in our water harvesting system. In addition helping reduce erosion, vetiver is also a palatable fodder species (Figure 5.3). We can harvest the young Vetiver with some frequency during the rainy season and maintain forage nutritional value (Table 5.3).

Table 5.3: *Nutrition quality of vetiver at various lifecycle phases. (Wikipedia)*

	Young Vetiver	Mature Vetiver	Old Vetiver
Energy [kcal/kg]	522	706	969
Digestibility [%]	51	50	-
Protein [%}	13.1	7.93	6.66
Fat [%]	3.05	1.30	1.40

We have also utilized Napier (*Pennisetum purpureum*) as a fresh cut forage for goats and cattle. Cows will readily eat it when we carry it to them in marginal pastures to supplement what is there. Napier is great because it can be vegetatively propagated (i.e. asexually propagated through cuttings). We are training three cooperatives in our region to use a variety of propagation techniques to see which are most effective for their dairy buffalo project—stay tuned! You can direct-plant napier cuttings or, if the dry season is pronounced, use some kind of nursery/cup starts and then transplant them into soil during the rainy season. We treat two- or three-node cuttings with Effective Microorganisms (EM1) and then dip them in a diverse blend of Vesicular-Arbuscular Mycorrhiza (VAM) inoculant, which is available from University of the Philippines, Los Banyos.

Figure 5.3: *Goats happily devour young vetiver leaves on an elevated feed rack.*

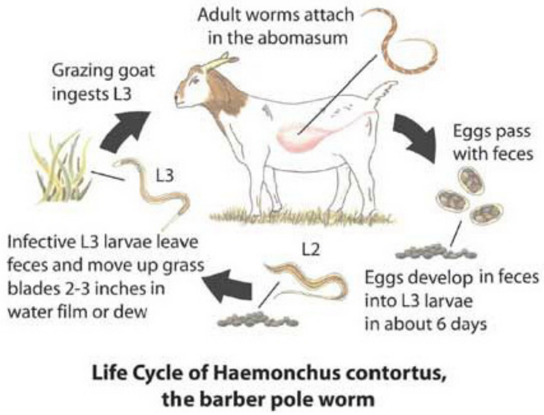

Figure 5.4: *Barber Pole Worm Life Cycle. Available: https://www.pinterest.com/pin/452541462542767238/*

The Aloha House has also utilized the Sloping Agricultural Land Technology (SALT) system since 2001. This system incorporates contour soil stabilization with legume trees and shrub perennials, as well as annual alley crops. The legume trees and shrubs can provide a nice forage option for ruminants; the legumes contribute protein for fermented feeds and contain vitamins as well as enzymes that boost feed digestibility (Watson 1985). Over the years, we have been able to save seed from prolific leguminous perennials. We have established stands and contours of *Desmodium rensonii* (Local name: Ticktrefoil), *Flemingia congesta* (Malabalatong), *Indigofera, Gliricidia sepium* (Kakawate or Madre de Cacao), *Leucaena leucocephala* (Ipil-Ipil), and *Mangium acacia*. These species are all well-suited for the SALT approach and are valuable legumes for goat feeds (Elvitch and Wilkinson 2008).

Prevention of Parasite Issues with Cut and Carry

In most pastoral areas, cattle do not face a threat of parasite infestation from the environment because they are immune to some of the common tropical pests that plague goats. Goats, however, are prone to certain parasites and are best grazed on dry pasture after the dew has evaporated or rains have dried, because barber pole worm infestation is aided by wet grass (Figure 5.4). Cut and carry legumes are always available to our goats and can be fed without risk of the parasite re-infecting the goats because the intestinal worm only lives in wet grasses. It is worth the management of cut and carry to protect against this parasite in most tropical areas.

Planned Grazing, Holistic Farm Management, Keyline Sub-Soiling, and Movable Electric Fences

P.A. Yeomen developed a concept called Keyline planning, based on the natural topography of the land; it uses the form and shape of the land to determine the layout and position of dams, irrigation areas, roads, fences, buildings, and tree lines (Ecologia 2012). His innovative Keyline plow has the ability to work subsoil without inverting the soil profile (Figure 5.5). Over a period of several months to a year, grasslands can be improved by pulsing the soil with successively deeper plowings ranging from 10 cm to 20 cm to 30 cm. With air and root matter being incorporated into the soil following deeper rips, greater microbial activity in pastures can be maintained through planned grazing. Abe Collins has documented his journey and published his findings through various avenues. His Keyline improvements are discussed in simple terms in an article he wrote with Darren Doherty (2009).

Figure 5.5: *Keyline plow for working the subsoil without inverting the soil profile.*

Collins has seen farmers add organic matter in pasture soils for many successive years, increasing organic matter by up to 7.3%. He utilizes complex mixtures of cover crop seeds—commonly between 7 and 20 varieties of seed in a single mix—to achieve multiple soil-health, production, and profit goals, usually in no-till farming systems (Collins 2013).

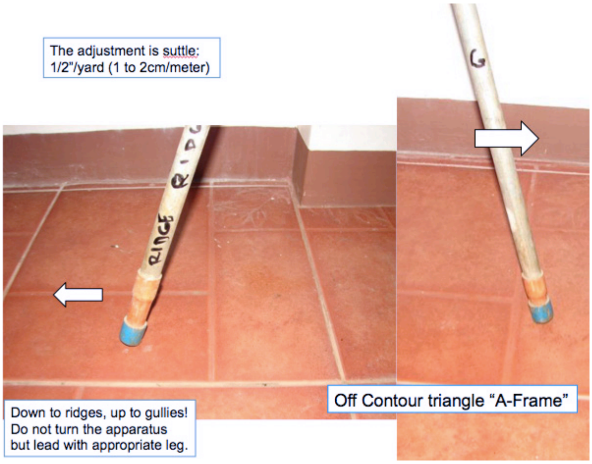

Figure 5.6: *Off contour triangle "A-Frame." An overview of this innovation is available for more study at this Slideshare set: https://www.slideshare.net/mik1999/keyline-without-a-tractor-for-small-farms-25014684*

Although tractors and Keyline subsoil plows are utilized in developed countries, we have innovated a modified Keyline method for small farms that does not require fancy machinery. With the use of an off-contour triangle "A-Frame," we are able to plant slightly downhill from the gullies to the ridges, drawing moisture to the ridges from otherwise over-hydrated gullies and thus increasing water availability throughout the year (Figure 5.6). By planting on the marked lines determined by the A-frame, we are able to draw more moisture through the root system and produce forage well into the dry season.

Electric Fence vs. Tethering

Combining aggressive pasture development with intensive grazing, we are able to increase stocking density and move our livestock frequently, often 2 to 3 times per day. With the help of a movable electric fence, our grazing cows can simulate the activities of the wild herds; historically, the wildebeest or great bison herds would graze in a tightly packed group (to keep the herd safe from predators), trampling the soil and adding manure. They would then move together to a fresh area when needed. Alan Savory modeled his herd management on this insight, as documented in his writings and TED talk.

When properly utilized, a movable electric fence allows farmers to move their herds in a dense grouping without over-grazing, so that all herbaceous plants are consumed and manure is spread evenly. When left to their own devices and free choice, ruminants will preferentially eat the most palatable greens and concentrate manure in a few areas. The least palatable species (often weeds) then prosper, shifting the pasture composition over time to these less palatable greens. Using planned grazing, Abe Collins has seen first year animals become very effective at managing aboveground pasture biomass while increasing root matter and biology below ground (2006).

Joel Salatin is another successful advocate of intensive managed grazing; he calls his method "Salad Bar Beef." He keeps his cows on perennial polyculture, being careful not to let the cattle overgraze on juvenile greens. Each pasture species has an "S" curve growth rate. If animals are allowed to graze an area too soon, plants will not have had enough time to recover. If animals are kept away too long, grasses will have reached a "geriatric" stage during which they turn dormant and lignify, providing less nutrition (Figure 5.7). Grazing should take place during the adolescent stage of a grass when optimum nutrition is available to the animal. For more information, see this video from Joel Salatin.

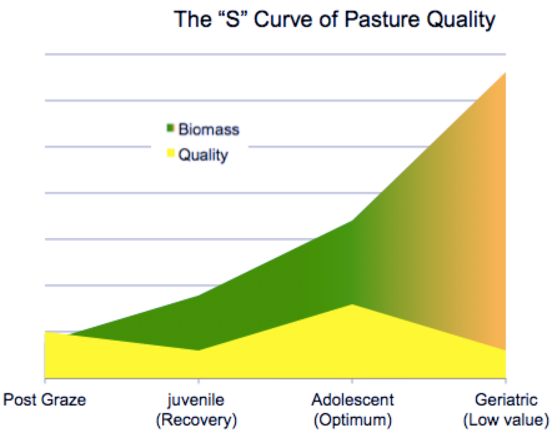

Figure 5.7: *The effect of time on pasture biomass and quality resulting in "S" curve growth rate.*

Movable electric fences may be too expensive for many farmers. Instead, small-scale farmers can tether their cows on a movable stake system. We were able to renovate old stands of *Imperata cylindrica*, commonly known as cogon grass, kunai grass, or blady grass, by tightly stocking and moving the herd according to observation of the needs of the pasture and the cows. We started by immediately grazing the new shoots after the natural seasonal burn-off that is common where cogon grass grows. (Do not feed the old standing dry cogon to your animals, because it is poor forage of low quality due to its maturation and lignification (see Figure 5.7). For cattle, we supplement the sub-standard graze of cogon with freshly cut and carried *Pennisetum purpureum* (Napier). Cows will readily eat Napier grass when it is carried out to marginal pastures in order to supplement their nutritional needs. Any Napier that is not eaten is trampled and left as mulch. Over a period of only 2 seasons in the tropics, we've seen the native turf grasses and *Brachiaria humidicola* take over these depleted pastures and biologically exclude the cogon!

Dairy Breeds

Here at Aloha House, we milk "native" cows, probably of Jersey descent, as well as Holstein and Brahman (or Brahma), which is a breed of Zebu cattle (*Bos indicus*). We recommend starting small with breeds that are locally available before you start investing money in exotic breeds. Thailand has a large national dairy center, in partnership with the Dutch Government in Saraburi; it is a great resource for large and small farmers alike. As farmers gained experience in managing dairy herds, the breeding plan of the center shifted from 75 percent Holstein-Friesian to 87.5 percent Holstein-Friesian crosses. These exotic breeds are now readily available to local farmers, as they have become "common." Thai farmers are also milking Zebu cows, and a Thai-Friesian breed has also been developed and tested (Chungsiriwat and Panapol 2009) (Figure 5.8). In Bangladesh, commercial dairy herds were most successful with Holstein breeds, compared to Jersey crosses, where success was measured by milk yield and herd health/adaptability (Azam *et al.* 2012).

Hay as Feed

In Chiang Mai, Thailand, we were able to visit a dairy cow co-op that trains and supplies farmers with Napier hay as well as other inputs. In Sri Lanka, small-scale farmers using semi-intensive management systems depend on tethering and stall-feeding as their main source of animal feeding; by

Figure 5.8: *The author's wife inspects a dairy herd in Thailand fed Napier hay.*

Figure 5.9: *Typical low-management cattle pasture: bunds and rice stubble.*

contrast, farmers in extensive management systems rely on grazing and tethering as the main source of animal feed. Animals are usually tethered and allowed to graze on paddy lands (bunds and harvest stubble and stover) (Figure 5.9), public spaces, and under rubber and coconut trees in estates. The average milk production under extensive management systems was 3.9 l/AU (Animal Unit)/day, while milk production under semi-intensive management systems was 5.4 l/AU/day, showing that the extra management may be worth the boost in production for small farms (Saraiva *et al.* 2014). Similar results were reported by Zemmelink *et al.* (1999) and Premaratne *et al.* (2013) in the mid-country wet zone of Sri Lanka. Lower average milk yields in extensive management systems may be due to poorer feeding and cattle management.

The Great Grain Debate

Tim Wightman, author of the *Raw Milk Production Handbook* (2005), addresses the question, "Should pasture-fed dairy cows get any grain?" Typical "grain-fed" dairy cows receive a large portion of their diet in the form of grain, resulting in high milk production but with lower milk quality and with a reduced lifespan for the cows. Pastured dairy cows with access to high-quality pasture and high-quality hay alone should be able to produce large quantities of milk. However, giving cows a small amount of grain can provide starch to feed the microorganisms in a cow's rumen that help the cow convert forage into body mass, milk, and energy. According to Wightman, "The rule of thumb, in order to manage rumen activity in cows, is to feed no more than one percent of body weight per day as grain." We use a blend of rice bran and copra meal at 1:1 ratio with a drizzle of molasses at the end of a day of grazing.

Azolla Successes and Failures as Ruminant Feed

Azolla (*Azolla caroliniana*) is a fast-growing floating fern with a reported protein range of 19-30%. We grow it intensively, and feed it to chickens, ducks and fish (See chapters 2 and 4)(Figure 5.10). Due to our abundance of napier and pasture, we are not currently using it for ruminants. Also, we have a finite supply of azolla and feed it to our hogs and poultry. However, experiments conducted by the Vivekananda Kendra-Natural Resources Development Project (VK- NARDEP) in Kanyakumari district, Tamil Nadu, indicated that the quantity and quality of milk yield of cattle went up when they were fed with azolla to supplement marginal pasture (Prabu 2007).

Azolla was introduced as an alternative feed for dairy cows by an NGO in India. In contrast to the VK- NARDEP study above, the pilot program was found to have very poor results (Tamizhkumaran and Rao 2012). This highlights the importance of testing innovations before promoting a community "solution," to ensure that a new technique or idea will work in your particular environmental and cultural context.

In experimental trials comparing common duckweed (*Lemna minor*), 'kang kong' or morning glory (*Ipomoea reptans*), water caltrap (*Trapa natans*), and *Salvinia cucullata* (often mistaken for azolla) in India, both duckweed and morning glory had higher feed conversion ratios and high protein: 28% and 32% respectively (Kalita *et al.* 2007; Biswas and Sarkar 2013). These excellent fodder crops can be grown in an aquaculture system, but should be kept away from the fish so as to ensure a regular harvest (otherwise the fish would eat them). I wish that azolla had been included in the India study. We feed available azolla (after it has satisfied the need for fish, chicken, and hog feed production)

Figure 5.10: *At our 15 degree latitude, azolla with 40-80% shade does better than azolla in full sun.*

to cattle by placing it in the evening feeder with our rice bran and molasses.

Figure 5.11: *A deep fryer basket works well for lifting the azolla while draining water.*

With floating water plants such as azolla and salvinia, a farmer must be careful not to over-harvest, 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 farmers should monitor which way of harvesting is more productive in their system. Azolla tolerates moving water better than duckweed. Salvinia is the fastest growing, but can be invasive. At Aloha House, our best interns in charge of azolla production averaged 194 grams/sq. meter. A deep fryer basket works well for lifting the azolla while draining water (Figure 5.11). We harvest in the morning and let the plants drip dry for 24 hours before weighing them (Mikkelson 2017).

Moringa Forage Can Improve Milk Production

According to Lowell Fuglie (2000) in Echo Development Notes #68, "New Uses of Moringa Studied in Nicaragua," when moringa leaves constituted 40-50% of dairy cows' feed, milk yields increased by 30%. The article shared: "The high protein content of moringa leaves must be balanced with other energy food. Cattle feed consisting of 40-50% moringa leaves should be mixed with molasses, sugar cane, young elephant grass, sweet (young) sorghum plants, or whatever else is locally available."

Feeding Other Ruminants

Water Buffalo

The tamaraw, or Mindoro dwarf buffalo, is a water buffalo endemic to the island of Mindoro in the Philippines. It is the only endemic Philippine bovine;

the species is endangered, with fewer than 500 animals remaining, and they are no longer used as draft animals. Most buffalo in the Philippines are much larger than the tamaraw. The Murrah is a domestic breed of water buffalo *(Bubalus bubalis)*, originally from the Punjab and Haryana states of India, that is kept for dairy production. Some areas in India specialize in buffalo dairy for the production of authentic Italian mozzarella cheese.

Draft animals may require less premium feed, depending on their workload. Napier grass is good to have available and readily transported as cut and carry to the work site. All traction animals require ample water and plenty of calories for the workload. Some molasses can supplement their energy requirements at 1-5% of daily feed ration. According to EDN 53, if you work with animal traction, you should also know about Tillers International. They have specialized information and training for a wide variety of working animals in developing countries. They even have draft animals in Madagascar ripping and sub-soiling on contour for water harvesting! See this link for more details.

Oxen, yaks, camels, llamas, alpacas, and reindeer are ruminants for someone else to write about, but think through the browse and graze needed before you buy feed. Often these native ruminants can be fed with proper planning from the bounty you develop on or around your farm!

Alternative Feeds For Goats

Goats are browsers, and need a different diet than can be provided by most pastures available to a smallholder farmer. Cut and carry legumes can round out goats' diet, but do not rely on a pure legume diet. When goats overeat lush, damp feeds such as clover, alfalfa, or cut and carry legumes, tiny bubbles of gas can get trapped in the rumen, causing bloat. It is a life-threatening condition; the foamy bubbles of gas are impossible for a goat to belch up. Protein levels vary from crop to crop but a rule of thumb is no more than 2/3 legumes and 1/3 grass and other forage should be given to goats.

Besides limited amounts of grass, shrubs, and cut and carry legume shrubs, we feed our goats a variety of palm leaves, bamboo, and neem. The neem is offered free-choice along with plenty of other greens, because it is a natural de-wormer and the goats will nibble as needed. It is reported to be very effective on sheep as well (Chandrawathani *et. al.* 2006).

Fresh coconut is another option for goat feed. Coconut farmers in our area drop the mature nuts and split them open with a machete for their goats. An American on our island has observed excellent results in his goats' overall health and weight gain and reduced his pastoral management on sandy soils by offering coconut to his goats on a daily basis. Research shows that copra meal (dried coconut meat) increases dietary intake of protein for cattle, goats, and sheep.

Copra meal is a valuable feed for ruminants and can be used as a protein supplement for grass-fed animals (Manikkamani 2011). If you use coconut by-products such as copra meal, be sure to avoid the second extraction using hexane. The chemical residues can be undesirable (Heuze V., *et al.* 2015).

By way of example, in North Sulawesi, Indonesia, a budding goat production system intercrops Napier grass (*Pennisetum purpureum*) under coconut groves. Their Crop Livestock System (coconut-forages-goat) also uses legumes such as Leucaena and Gliricidia. This is another example of an integrated and sustainable practice that helps with "the scarce supply of good forages (grass and legume) to support the feed requirements of goats." Of course, the manure from the feed is converted to organic fertilizer. It is a way to achieve better growth of both pasture and coconut yeild (Polakitan *et al.* 2001).

Sheep

Many straggly sheep wander the tropics, surviving but rarely thriving. Goats might be a better entry way for the novice, but lamb and sheep can have a niche in the right climate under good management. Sheep are prone to deheydration and only drink clean water from still ponds or drink pails. Moving water, streams, and rivers will not help in your watering program. They are also in need of protection from predators. Sheep are more suited for cooler climates because they can get heat stroke easily. The good news is that although there are important differences between lamb breeds, research in Brazil found that sheep can be finished exclusively on tropical pasture (Poli *et al.,* 2013).

Silage for Ruminants

We utilize fermented feeds quite a bit for our fish, hogs, and poultry. However, we do not ferment or ensile any of our grasses, grains, or legumes for our four-stomached friends. We find that, on a small farm, the added labor and management negate any savings. E. coli can be problematic, because acidosis (too much acidity in the body) can result from fermented feeds and E. coli will flourish in the rumen under those conditions. Feed lots struggle with high E. coli counts because the bacteria survive the high acid (low pH) environment and multiply. The fermented feed does not culture E. coli, but rather the cows, goats, etc. produce high levels in their waste stream. The manure and feed yard are the disease vector. According to the Reference Advisory Group on Fermentative Acidosis of Ruminants (RAGFAR): "Rumen pH starts to decline immediately after feeding concentrates or silage. Concentrates such as grain, soy, or corn can cause even a more rapid decline in rumen pH than silages" (RAGFAR 2007). We are a raw dairy operation and avoid silage altogether. We do not pasteurize our milk. To keep our milk safe, we eliminate exposure to E. coli by avoiding concentrates and silage and feeding our ruminants our grass/greens; therefore, we have a lower risk for E coli contamination than a feedlot using grains only. You can read about our silage for hogs in chapter 3 and adapt it for ruminants, but be careful to substitute legumes for fishmeal and to avoid soy meal. In India a technique has been demonstrated for cattle feed fermentation.

Documented Problems with Soy

At Aloha House, we do not feed soy to any of our livestock, due to soy's detrimental health effects. Soy contains phytoestrogens and enzyme inhibitors that are problematic for both livestock and humans (IEH 2000). My concerns with soy have been previously summarized in chapter 4. We at Aloha House also choose to avoid genetically modified organisms (GMOs).

Conclusion

Farmers feeding cows, goats, sheep, and buffalo should attempt to keep purchased inputs to a minimum. Farmers must balance the dietary needs of their animals with safety, comfort, and security from theft. No matter how ideal your goals for your ruminant herd, make sure you carefully plan and manage for the overall benefit of the animals and the farmer. Most small farms in SE Asia would do well to develop and manage some amount of pasture for ruminants, combined with a cut and carry strategy. Manure should be incorporated on the farm to maintain soil fertility for the forages and plants, and tighten nutrient cycling loops so that the benefits of integrated livestock will translate into more economical and sustainable food production.

Aloha House cut & carry training

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