Chapter 6

Utilization of Organic Resources in Fish Farming

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Aquaculture involves the cultivation of aquatic organisms under partial or fully controlled conditions. Aquaculture in Kenya dates back to the colonial time (Vernon and Someren, 1960) but has faced a number of of constraints that hindered its development. Among the major constraints are limited varieties of the cultured fish species and unavailability of inexpensive, locally-available diets.

At the Sagana Aquaculture Research Station in Central Kenya, efforts are underway to intensify the culture of Nile Tilapia (*Oreochromis niloticus)* and African Catfish *(Clarias gariepinus)*. Several experiments have been conducted and others are in progress to evaluate different fish feeds, both as single ingredients and in combination. Liti and Mugo (2002) evaluated the performance of single ingredients of rice bran, wheat bran and maize bran in combination with diammonium phosphate (DAP) and urea. Results from the study demonstrated that both wheat and maize bran produce similar fish yields but are more productive than rice bran. The study also revealed that fermentation of the bran does not enhance fish yields. A cost-benefit analysis showed that wheat bran is the most effective bran to use, followed by maize bran while rice bran offers the poorest returns. It is therefore recommended that rice bran should only be used when other superior feeds are not available.

Organic Resource Utilization in Fish Farming:

Aquaculture production techniques can be categorized based on management intensity. Extensive culture technique occurs where natural productivity meets all the nutrient requirements of fish. Semi-intensive culture occurs when ponds are fertilized with either organic or inorganic fertilizers to stimulate natural production or when supplemental feeds are used to increase fish yields. Intensive culture occurs when all the nutritional requirements are met externally through formulated diets. The semi-intensive system is most widespread in Africa as feed requires over 50% of the operating costs of more intensive production systems (Pillay, 1992). Our work has focused upon the use of under-utilized organic materials and agricultural by-products as replacement feeds in fish production. Formulated fish diets are expensive and not readily available to small-scale farmers, in contrast to commercial livestock feeds. As a result, in most developing countries, agricultural by-products used as organic inputs to ponds and single ingredient diets offer opportunity to improve fish farming, and these materials may be effectively combined to compliment their various nutritional properties.

A number of organic materials are commonly used in Kenya as aquacultural fertilizers including chicken manure and bedding, duck droppings and cow, sheep, goat and pig dung. Others include green manure such as cut fodder and tree prunings. Organic fertilizers may also be applied to fishponds to stimulate natural food production as these inputs increase autotrophic and heterotrophic food webs. The soluble fraction supplies nitrogen and phosphorus that supports primary production by phytoplankton. The particulate component provides food and substrates for microorganisms (e.g. bacteria, protozoa) as well as acting as direct food for the fish. Most of the nutrient release occurs within a few days after addition of manure to the pond, primarily through leaching and breakdown of soluble organic matter (Nath and Lannan, 1992). Some of the advantages and disadvantages of using organic and mineral fertilizers as inputs to fish ponds are presented in Table 1. The carbon dioxide released after decomposition provides the inorganic carbon needed for photosynthesis or slowly enters the carbonic acid-bicarbonate - carbonate system that acts as a pH buffer. This buffer is important in protecting fish and other aquatic organisms from the adverse effects of pH fluctuations. Parts of the organic material settle as pond sediments that significantly contribute towards seepage reduction.

Table 1. Advantages and disadvantages of organic manures over mineral fertilizers in fish farming

Organic Residue	Mineral Fertilizer
Advantages	
Provides carbon in addition to phosphorus and nitrogen	Does not supply carbon
Supports both autotrophic and heterotrophic food webs	Supports only autotrophic metabolic pathways

They are less expensive	They are more expensive
They increase the buffering capacity of a pond (alkalinity increases with time)	They decrease the buffer capacity of a pond (decrease alkalinity with time)
Often in close proximity to ponds, less transportation costs involved	Usually imported, with higher associated transportation costs
Reduces pond seepage	Does not reduce pond seepage
Disadvantages	
Requires processing before application	No processing before application
Has higher biological oxygen demand	Has less biological oxygen demand
Stains pond water reducing transparency	No colour imparted to water
Bulky and difficult to handle	Not as bulky and easier to handle

Fish yields are determined by several factors that include the quantity and quality of diets. The primary goal in fish farming is to transform dietary protein into fish protein (Jauncey, 1982). Protein sources in fish diets are mainly of two types, animal protein and plant protein. Inclusion of animal protein into fish diets significantly increases production costs. As proteins are generally too expensive for use in fish feed, except as feed supplements, the focus of attention becomes maximizing the efficiency of low cost plant proteins and farm wastes.

The most utilized agricultural by-products used as fish feeds in Kenya include maize, wheat and rice bran, and cotton, soybean, and sunflower seed cakes. They are normally used to supplement natural food (plankton and detritus) in the ponds. The quality of particular bran depends on the locality and the methods of processing. For example, rice bran from Mwea rice factory has a crude protein content of approximately 10% (Veverica *et al.,* 1998), however, after the collapse of the factory, individual processors emerged, and the rice bran obtained from these processors contained between 3-6% crude protein (Liti and Mugo, 2002). It was later observed that the individual processors often mixed their bran with ground rice hulls which reduced the protein content. Wheat bran is of more reliable quality with a crude protein content of 14-17%. This reliability results from the larger-scale processing of wheat. The nutrient concentrations of several feeds are presented in Table 2.

Most fish farming in Kenya relies heavily on natural food in the pond system with some supplementation of artificial feeds to increase fish yields. The feed supplements are mostly agricultural by-products that do not provide complete fish nutrition. Most of these supplements are readily available and are not utilized as human food. Farmers throughout the country have access to different feedstuffs, depending on locality. For example, a fish farmer in Kitale has better access to maize bran which is also less expensive and of more reliable quality compared to wheat or rice bran, which are relatively scarce in the area. Fish farmers near the Mwea irrigation scheme, and Ahero near Kisumu have better access to rice bran while farmers in Uasin Gishu have seasonal accessibility to wheat bran. Nonetheless, each of these materials is bagged and marketed throughout the country for use as livestock feed.

Ingredients	Nutrient Concentration					
	dry matter	protein	lipid	NFE[1]	crude fibre	ash
	----------------------------------%-----------------------------------					
Brewers yeast	93.0	25.0	15.4	32.0	21.9	4.7
Shrimp meal	91.0	55-60.0	6.0	5.0	4.0	23.1
Cotton seed Cake	93.0	35.9	6.7	44.5	7.1	5.8

Sunflower Cake	94.0	21-25.0	5.5	29.2	39.6	5.0
Wheat bran	-	14-18.0	6.5	59.5	16.0	4.0
Maize bran	93.0	10-15.0	4.4	70.8	11.6	3.2

[1]NFE- nitrogen free extracts.

Single ingredients are often deficient in one or more of the nutrients required for growth. To overcome the deficiency, ingredients are mixed together to form a compounded feed. Formulated feeds are usually more expensive than single ingredients and therefore are formulated for species that fetch higher market prices, such as rainbow trout (*Oncorhynchus mykiss*). Compounded feeds for Nile tilapia (*O. niloticus*) and African catfish (*C. gariepinus*) are scarce and relatively expensive in Kenya, however, diets formulated for pigs and young broilers are suitable alternatives.

Figure 1. A formulated feed that is more effective in increasing fish yields than single-ingredient feeds.

Several compound feeds were tested at Sagana and different commercial diets were similar in promoting fish yields and better than rice bran. Currently, on-farm formulated feeds are being tried against single ingredients and a commercially-available livestock feed (Figure 1). Preliminary results from this study have again shown that formulated feeds are more effective in increasing fish yields than single-ingredient feeds. Since animal protein is scarce and more expensive than plant protein, another experiment was designed to evaluate whether animal protein inclusion could be reduced from 12% to 6% in the diets of Nile tilapia. Preliminary results indicate that the amount of animal protein can be reduced from 12% to 6% without loss in fish performance but cannot be replaced entirely by plant protein. Table 3 presents two possible formulations using three ingredients that yield a high protein diet for tilapia. Table 4 combines five ingredients in the formulation of a diet containing 20% crude protein that may be combined using materials commonly marketed by retailers of livestock feeds. There was no improvement when supplemental vitamins were added to the feed, suggesting adequate supply of vitamins from the natural food.

Table 3. Two formulations for Nile tilapia feed (*Oreochromis niloticus*) using three ingredients that produce a diet with 25% crude protein from locally-available materials.

Ingredient	Inclusion	Protein	Lipid	Crude fibre
	--------------------------------% ----------------------------------			
Shrimp meal	5.0	3.0	0.3	0.2
Cotton seed cake	39.7	14.3	2.7	2.8
Wheat bran	55.3	7.7	3.6	21.9
Total	100.0	25.0	6.6	24.9
Alternative Formulation				
Shrimp meal	5.0	3.0	0.3	0.2
Cotton seed cake	48.3	17.3	3.2	3.4
Maize bran	46.7	4.7	2.1	5.4
Total	100.0	25.0	5.6	9.0

Table 4. Dietary formulations for Nile tilapia (*Oreochromis niloticus*) using five ingredients required to make a diet with 20% crude protein from locally available materials.

Ingredient	Inclusion	Protein	Lipid	Crude Fibre
	----------------------------------% ----------------------------------			
Water Shrimp	8	4.8	0.5	0.3
Cotton seed cake	8.1	2.9	0.5	0.6
Wheat bran	62.1	8.7	4.0	9.9
Sunflower cake	4.4	1.9	0.2	0.7
Maize bran	17.4	1.7	0.8	2.0
Total	100	20	6	13.6

Use of Organic Resources for Fish Farming at Sagana

The Sagana fish farm is a leading aquaculture research and development center in Kenya that is operated by the Fisheries Department. The main activities at the station include extensio services, training and research in fish production. The farm is located at 0°39'S and 37° 12'E and at an altitude of 123 0 m above sea level. It is situated 105 km northeast of Nairobi. The facility contains a modern hatchery, holding tanks, feeder canals, production ponds and integrated fish, livestock and poultry facilities. Integrated farming applies to systems that are aimed at improving the diversity and production of a whole farm. This type of system allows for efficient utilization of farm wastes. Such a system has been set up at Sagana to boost fish production. Integration is achieved through strategic construction and placement of a zero grazing units, poultry and duck pens and sheep rearing facilities.

Figure 2. Integrated fish production and poultry rearing at Sagana aquaculture station. The use of organic fertilizers has been of great importance in enhancing fish yields at the station

Manure from the cattle shed is flushed into a 1.6 ha fishpond constructed a few meters adjacent to the cattle shade. The cattle unit is located at a slightly higher elevation and a controlled water flow is allowed to flush through it to wash manure into the pond, thus reducing transportation costs. The manure promotes natural food webs that improve tilapia and catfish production. Diana *et al*. (1994) demonstrated that organic fertilizers result in higher primary production and consequently larger tilapia and catfish yields, apparently due to increased production of both autotrophic and heterotrophic organisms.

The use of poultry droppings is facilitated by stocking chicken and ducks in pens constructed directly over the ponds (Figure 2). Chicken manure fertilizes the water below and is also consumed directly by fish. Discarded chicken feed becomes part of the fish diet as well. The reduced transportation cost increases profit margins, which is the main goal of most commercial farmers. We recommend the use of organic inputs in fish production and have identified those organic materials that promote heterotrophic activities which in turn promote fish yields. Although in Sagana both chicken and ducks are reared, an earlier study demonstrated that ducks are better than chicken in poultry/fish integration. Ducks raised adjacent to ponds appear to be hardier and less susceptible to diseases than chickens. In addition, they are easier to house because marshy riversides and wetlands serve as excellent quarter for duck farming.

There is a broad range of organic materials used in fish farming at the Sagana facility, however, the choice of materials used as feed greatly affects fish yields. The allocation of organic resources in fish farming also depends upon fish species, local water conditions and the intensity of pond management. Annual fish production ranges between two to nine tons ha^{-1} yr^{-1}, depending on the quality and amount of feed.

Figure 3. Feeding the fish at designated corners of the fish ponds. Natural food provides adequate vitamins for Nile tilapia in semi-intensive culture ponds.

Several studies conducted using rice bran as feed have consistently produced yields of Nile tilapia between 2.4 to 3.0 tons ha^{-1} yr^{-1}. Veverica *et al*. (1998) reported Nile tilapia yields of 4.0 ton ha^{-1} yr^{-1} in fertilized static earthen ponds while Liti *et al.* (2002) reported Nile tilapia yields of 5.0 ton ha^{-1} yr^{-1} under similar conditions. Experiments with wheat and maize bran produce yields of 6.0 tons ha^{-1} yr^{-1}. Under similar conditions, formulated feeds provide Nile tilapia yields of 7.5 ton ha^{-1} yr^{-1}. Two diets, one containing vitamin premix and the other without, were compared. The two treatments did not show any significant differences. From these observations, it was concluded that there was no need to supplement the diets with vitamin premixes. This observation suggested that natural food provided adequate vitamins for Nile tilapia in semi-intensive culture ponds (Figure 3)

Conclusion

Development in the aquaculture industry will depend upon better utilization of organic materials, particularly as fish feed. Other uses include the addition of organic materials that provide substrate to aquatic food webs that indirectly serve as feed. One way of achieving these goals or organic resource utilization is to develop training activities in integrated aquaculture. In more integrated systems, farm wastes from other enterprises can become converted into higher-value inputs to nearby fish ponds. Similarly, effluents and sediments from fish ponds may be profitably applied to croplands.

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