Analysis of feeds and fertilizers for sustainable aquaculture development in Kenya

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SUMMARY

The expansion of the agricultural sector is crucial for the overall economic and social growth and development of Kenya. In 2003, the sector contributed 24 percent to Gross Domestic Product and a further 27 percent through linkages with manufacturing, distribution and service-related sectors. The agriculture sector, which comprises agriculture, livestock, fisheries and related activities, also supports an estimated 75 percent of the population. In addition, 87 percent of all poor households live in rural areas where farming is their main activity. About 50 percent of Kenyans are food insecure, while significant potential for increased production remains largely unexploited. About 66 of the manufacturing sector is agro-based.

The major cereal crops of Kenya are maize, wheat, rice, sorghum, millet and barley among others. Together with cassava, sweet potatoes and soybeans these crops represent the major food crops farmed in Kenya and there is little or no surplus for the animal feed industry. It is estimated that feed manufacturers use 450 000 tonnes of raw materials annually, of which about 2 200 tonnes of fishmeal is imported from Tanzania. The Kenyan animal feed industry is comprised of a formal and an informal sector. The formal sector is represented by the animal feed manufacturers association of Kenya. There are about 80 registered feed manufacturers in the country of which 17 are considered large scale. At this stage the industry is largely unregulated; hence feed quality is often a major problem. The growth of the fishmeal based animal feeds industry during the last decade has resulted in an unprecedented demand for silver cyprinid *Rastrineabola argentea* (locally known as omena), the second most important commercial fish species in Lake Victoria and Nile perch skeletons as raw material for animal feeds and fishmeal, respectively. It is feared that this will lead to a severe reduction of omena and Nile perch by-products for human consumption.

Approximately a third of Kenya's 5 900 fish farmers are commercial farmers although only four are large scale commercial enterprises. The remainder are rural, non-commercial, small-scale fish farmers. Total fish production is currently estimated at around 1 000 tonnes. Culture systems range across the spectrum from small-scale extensive to semi-intensive pond based polyculture of Nile tilapia, *Oreochromis niloticus* and North African catfish, *Clarias gariepinus* to intensive pond, tank, raceway and cage monoculture.

Though animal manure is generally available its use in small-scale aquaculture is limited. Chicken manure is very expensive and on a unit weight basis approaches the price of chemical fertilizers. This is a major problem. Chemical fertilizers are only used by larger commercial enterprises.

The main protein sources of farm-made feeds are oilseed cakes (cotton, soybean and sunflower), fishmeal, bloodmeal, carcass meal and lake shrimp, though fishmeal is very scarce. Cereal bran, kitchen waste and vegetables are commonly used by the non-commercial farmers. Many commercial farmers, irrespective of scale, have developed their own highly successful formulations and make their own pellets using crude machinery such as meat mincers, while others modify poultry and pig feed formulations. Farm made feeds are fed either as a moist dough, in pellet form or as a dry meal. Only two aquaculture feeds are produced in Kenya, a tilapia pellet and a rainbow trout pellet. These are expensive and hence most commercial farmers compound and manufacture feeds on the farm. Recommendations to address the constraints facing the development of aquaculture are provided.

1. OVERVIEW OF AQUACULTURE PRACTICES

Kenya has extensive bodies of both inland and coastal waters in which aquaculture can be practiced, either on an intensive or extensive scale. Though there are several experimental mariculture initiatives, aquaculture is presently only practiced in inland waters and comprises about 0.6 percent of the total national fish production.

Traditionally, fish farming has mainly been practiced at a subsistence (non-commercial) level. Of the 5 890 registered fish farmers in 2005 only 4 (0.1 percent) were large scale farms, 1 962 (33.3 percent) were small-scale commercial farms and 3 925 (66.6 percent) non-commercial farmers. The increases in production since 1999 have been negligible and official statistics report that approximately 1 035 tonnes were produced in 2004 (Table 1).

TABLE 1
Trends in total fish production and percent contribution by aquaculture to total annual fish yield (1999- 2004)

Year	Total fish yield (tonnes)	Aquaculture production (tonnes)	Aquaculture as % of total fish production
1999	214 712	984	0.46
2000	202 639	967	0.47
2001	164 274	998	0.60
2002	128 227	998	0.78
2003	119 688	1 012	0.85
2004	134 741	1 035	0.77

Source: MLFD (1999–2004)

TABLE 2
Comparison of returns from crop and fish farming in Kenya, 2003

Farming activity	Production (kg/ha/year)	Net annual revenue (US$/ha/year)
Fish (Western Kenya)	7 400	6 420
Fish (Central Kenya)	3 500	4 095
Coffee	2 471	488
Tea	6 000	59 289
Tomato (rain-fed)	9 884	2 604
Tomato (irrigated)	9 884	10 418

Source: Anon (2003)

Average exchange rate (2005): US$1.00 = Ksh75.6

The land tenure system in Kenya curtails land ownership by farmers. Consequently 80 percent of farmers hold small plots of land, normally less than 2 ha. Cultivation of staple and cash crops (mainly tea and coffee for export) forms the backbone of small-holder farming in Kenya. Despite the seemingly higher returns from fish farming (Table 2), farmers pay more attention to crop farming. This may suggest one of two things, either that the calculated returns from fish farming are unrealistic or that farmers are averse to the associated risks of fish farming. Underpinning their activities is a well-developed agricultural research, extension and marketing system. The livestock production sector in Kenya has a well developed extension system with partly privatized veterinary services.

The current development goals of the Kenyan government focus mainly on alleviating poverty, increasing food production and addressing environmental degradation. Since independence, the increase in food production has been below the average population growth rate. Several strategies have been developed to address this, including intensification of existing technologies, increasing the genetic potential of staple and cash crops, developing capture fisheries and livestock production and encouraging the development of large-scale commercial aquaculture.

The choice of aquaculture systems in Kenya is dependent largely on the financial status of the farmer. Several systems are employed and these are listed below:

- intensive pond monoculture of Nile tilapia, *Oreochromis niloticus* and rainbow trout, *Oncorhynchus mykiss*;
- intensive cage culture of Nile tilapia;
- intensive fingerling production of North African catfish, *Clarias gariepinus* (currently there are six commercial catfish hatcheries producing between 10 000 and 20 000 fingerlings per month, mainly as live bait for the long line Nile perch, *Lates niloticus* fishery in Lake Victoria);
- semi-intensive pond monoculture of North African catfish and Nile tilapia (and other tilapia's);
- semi-intensive pond polyculture of North African catfish and Nile tilapia;
- extensive pond monoculture of tilapia and common carp, *Cyprinus carpio*; and
- extensive pond polyculture of Nile tilapia and common carp.

TABLE 3
Aquaculture production statistics (2000-2004), excluding production from Government stations

Indicators	2000	2001	2002	2003	2004
Total no. of farmers	**7 501**	**8 371**	**7 840**	**7 790**	**5 890**
Total area of ponds harvested (ha)	**27.36**	**16.77**	**88.0**	**19.9**	
Tilapia production (weight in tonnes) by small-holder, non-commercial farmers in extensive and semi-intensive systems	31.69	70.31	17.16	*	19.76
Tilapia production (weight in tonnes) by commercial farmers in semi-intensive or intensive systems	42.75	*	33.43	27.78	42.13
Total tilapia production (value in US$)	66 438	85 799	56 474	*	20 405
Catfish production (weight in tonnes) by commercial farmers in semi-intensive system	1.51	*	*	*	8.64
Catfish production value (value in US$)	1 453	*	*	*	5 796
Common carp production (weight in kg) by small-holders in extensive systems	675	*	*	*	*
Common carp production value (value in US$)	725	*	*	*	*
Trout production (weight in tonnes) by commercial farmers in intensive system	3.8	1.8	2.5	*	2.5
Trout production value (value in US$)	23 806	17 235	16 541	*	32 052
Total production (tonnes)	**80.4**	**72.1**	**58.6**	**72.0**	**73.09**
Total value (US$)	**71 738**	**103 034**	**78 872**	**89 434**	**104 291**

* Data not available

Source: MLFD (2005)

Fish holding systems include, earthen or concrete ponds, PVC lined earthen ponds, locally assembled cages, concrete raceways and metal tanks.

Approximately 35 percent of tilapia produced in Kenya is produced in semi-intensive systems, while 65 percent is produced in extensive systems. Aquaculture production statistics are summarized in Table 3. Production of common carp in Kenya has virtually stopped and this is most likely due to consumer preferences.

2. ANALYSIS OF FERTILIZERS AND NUTRIENTS

2.1 Availability and accessibility of fertilizers

Poultry and cattle comprise the bulk of livestock production in Kenya. Table 4 shows that there were 11.4 million head of cattle in 2000 and by 2004 this had increased to 13 million. Poultry production has been fairly stable at around 26 million birds per annum.

The amount of organic manure produced on the basis of the national herd in 2004 was approximately 18.8 million tonnes. However, most of the manure is produced from pastoralism and is therefore not readily available for both agriculture and aquaculture. The bulk of the available manure is used for crop production and only a small, non quantified proportion is used for aquaculture. Most small-scale farmers use "green compost" in pond cribs. Accurate data of the quantity of manure used in aquaculture is lacking. In Kenya, the recommended manuring rate for fish ponds is 500 kg/ha/week.

The most commonly used chemical fertilizers by commercial farmers are di-ammonium phosphate (DAP) and urea. From a nutrient supply perspective these are also the cheapest sources of nutrients in the country. For example, the price for dry chicken manure in 2005 was US$400/tonne compared, to DAP and urea, which sold at an average price of US$470/tonne (Table 5).

TABLE 4
Kenya livestock population (thousand) during 2000-2004

Sector	2000	2001	2002	2003	2004
Cattle	11 445	11 476	11 940	12 531	13 022
Sheep	7 940	7 609	9 289	8 157	10 230
Goat		10 804	11 319	11 947	13 391
Pig	311	333	336	415	380
Poultry	26 292	27 031	27 871	28 283	26 240
Donkey	416	479	521	424	516
Camel	718	819	847	895	1 194

Source: MLFD (2004)

2.2 Fertilizer management strategies

Small-scale, non-commercial farmers fertilize their ponds using the crib or the bag method. The crib comprises

about 10 percent of total pond size and is loaded with vegetation that rots and gradually releases nutrients into the water. The crib compost is turned weekly to facilitate nutrient release. Alternatively a gunny bag is filled with 5-10 kg dry chicken or goat manure and tied to a corner of the pond. The bag is shaken frequently (once a week) to facilitate the release of nutrients. One bag is used per 200 m^2 and farmers are encouraged to add manure on a weekly or fortnightly basis.

TABLE 5
Price of organic and inorganic fertilizers in Kenya (2005)

Fertilizer	Cost (US$/kg)
Di-ammonium phosphate (DAP)	0.50
Triple super phosphate (TSP)	0.47
Lime ($CaCO_3$)	0.05
Murate of potash	0.49
Urea	0.44
Calcium ammonium nitrate (CAN)	0.40
Chicken manure (dry)	0.40
Cattle manure	0.13
Pig manure	0.06

Source: Author's survey (2006)

Manuring rate depend on the size of the pond. Maximum recommended application rates are 50 g of dry manure per square metre per week (5 kg/100 m^2/week). Most farmers do not weigh the manure they use in their ponds, but measure turbidity to regulate their manuring schedule by monitoring algal blooms and using Secchi disk depth. Ponds are fertilized when Secchi disk depth exceeds 15 cm.

Chemical fertilizers are only used by commercial farmers who practice semi-intensive aquaculture in ponds. The fertilizer is dissolved in a bucket of water and the solution sprinkled onto the water surface at various localities. Application rates for DAP and Urea are 2 g/m^2/week (15 tablespoonfuls/100 m^2/week) and 3 g/m^2/week (about 30 tablespoonfuls/100 m^2/week), respectively. This combination of DAP and Urea is equivalent to 20 kg N/ha/week and 8 kg P/ha/week. These rates are recommended for warmer areas, whereas in cooler areas half the rate is applied.

To reduce pond acidity, commercial farmers apply agricultural lime to earthen ponds. Lime is applied at a rate of 20 g/100 m^2 for red soil, whereas black cotton soil may require more. One week after application the ponds are filled with water.

3. ANALYSIS OF FEEDS AND FEEDING

3.1 Availability of feed ingredients

As mentioned earlier the major cereals produced include, maize, wheat, rice, sorghum, millet and barley among others, and together with cassava, sweet potatoes and soybeans these crops represent the major food crops farmed in Kenya (Table 6). These crops also form the main staple foods of the population and there is little or no surplus for the animal feed industry (MOA, 2004). It is estimated that feed manufactures use about 450 000 tonnes of raw materials annually, worth about 6 billion Kenya Shillings. Approximately 2 200 tonnes of omena fishmeal[1] is imported from Tanzania to support the local industry (AKEFEMA, 2005). The wheat deficit is imported from Pakistan, Russia and the United States of America (Table 7). Kenya

TABLE 6
Food crop production statistics (2002-2004)

	Production (tonnes)		
Crop	2002	2003	2004
Maize	2 408 596	2 710 848	2 138 639
Rice	45 099	40 502	49 295
Millet	72 197	63 622	50 467
Cassava	746 974	521 975	443 000
Sweet potato	434 774	615 458	571 293
Soybean	*	779	653
Sorghum	115 584	127 215	69 508

*Data not available.

Source: MOA (2005)

TABLE 7
Wheat production and import, 2000-2003

Year	Production (thousand tonnes)	Production (% of total requirement)	Import (thousand tonnes)	Import (% of total requirement)	Total (thousand tonnes)
2000	74	10	636	90	710
2001	82	12	617	88	699
2002	60	10	515	90	575
2003	64	11	502	89	567

Source: MOA (2003)

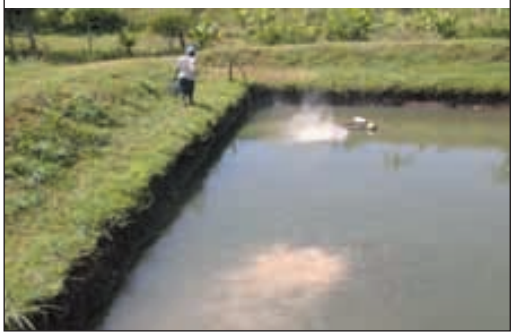
[1] Fishmeal produced from silver cyprinid *Rastrineabola argentea* (locally known as omena), the second most important commercial fish species in Lake Victoria.

imports 98 percent of its vegetable oil requirement, mostly from Malaysia. The severe shortage of suitable feed ingredients continues to be a serious constraint faced by the animal feed industry (AKEFEMA, 2005).

There are two rainy seasons in Kenya when crops are planted:

- long season (April-July), crop planting takes place from March-April and harvesting is from July-September; and
- short season (October-December), crop planting takes place in October and harvesting is from January to February.

FIGURE 1
Supplementary feeding of tilapia with omena dust mixed with maize bran in Bondo, Western Kenya



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Agricultural by-products most frequently used as single fish feeds or as ingredients for compounded feeds include cereal bran (maize, wheat and rice) and oilseed cakes (cotton, soybean and sunflower). The quality of bran is highly variable and depends on the locality and the method of processing. For example, rice bran from Mwea Rice Factory had a crude protein content of approximately 10 percent (Veverica, Were and Gichuri, 2002), however, after the collapse of the factory, other processors emerged and the rice bran obtained from these processors contained between 3-6 percent crude protein (Liti and Munguti , 2003). It was later observed that processors often mix their bran with milled rice husks thus reducing the protein content. Wheat bran obtained from industrial processors is of a more reliable quality with a crude protein content of 14-17 percent. Nonetheless, all of the materials mentioned above are marketed throughout the country for use as livestock feed, though availability depends on the season, the region and demand.

About 99.9 percent of the small-scale, non-commercial tilapia farmers in Kenya rely primarily on natural pond productivity with some supplementation of agricultural by-products as feed to increase yield (Figure 1). Most of the supplementary feeds are readily available and are not utilized as human food. The price of agricultural by-products and other pond inputs is highly variable on a seasonal and a regional basis and this is illustrated in Table 8 and the average price of common fish feed ingredients or supplementary feeds is shown in Table 9.

Fishmeal, bloodmeal, carcass meal, oilseed cakes and Lake shrimp (*Caridina niloticus*) are the main protein sources in farm-made aquafeeds. Fishmeal, in particular, is a scare commodity. Local production of fishmeal is shown in Table 10. The crude protein level of ingredients is often variable and care should be taken when incorporating

TABLE 8
Regional prices of pond inputs, 2004

Commodity	Price (US$/tonne)					
	Nairobi	Rift Valley	Western Kenya	Nyanza region	Central Kenya	Coastal region
Wheat bran	100	80	90	90	100	120
Maize bran	90	80	90	90	90	90
Rice bran	90	100	100	80	80	90
Cattle/sheep/goat manure	260	10	130	260	130	10
Chicken manure	530	400	400	400	400	360
Pig manure	60	60	60	60	60	60
Lake shrimp	400	330–400	260	200	400	660
Omena fishmeal	660–990	530–660	400–460	360	990	925–1 125

Source: MLFD (2005)

TABLE 9
Price of locally available feed and ingredients, 2004

Ingredient	Cost (US$/kg)
Rice bran	0.08
Maize bran	0.09
Wheat bran	0.13
Brewers waste	0.03
Cotton seed cake	0.26
Groundnut cake	0.40
Blood meal (raw)	0.03
Fishmeal	0.53
Grower mash	0.24
Layer mash	0.24
Dairy meal	0.22
Pig finisher	0.19

Source: MLFD (2005)

these ingredients into feeds. For example, the crude protein content of Lake shrimp varies depending on season, fishing area and handling from 40 to 60 percent. Other high protein resources used on ornamental fish farms and catfish and tilapia hatcheries include liver, egg yolk, *Artemia*, rotifers or other zooplankton and powdered (skimmed) milk.

Vegetable oils from cotton seed and soybeans are the main sources of lipids in fish feeds, while cassava starch is often used as a binder.

Vitamins and mineral premixes are only included in commercially manufactured feeds. The use of pigment enhancing feed additives is restricted to a few ornamental fish producers who use naturally occurring material e.g. carotene from carrots, sweet potato and cassava leaves. However, the qualitative and quantitative use of these materials is not documented. There is no documented use of preservatives in fish feeds in Kenya. The proximate composition of some of the more common supplementary feeds or ingredients is provided in Table 11.

TABLE 10
Fishmeal production and import, 2005

Type	Local Production (tonnes)	Source of raw materials	Price (Ksh/kg)	Import	Cost (Ksh/kg)
Marine	7	Tuna waste (head, tail, bones, skin and gut)	18	Nil	NA
Freshwater	15	Nile perch waste (head, tail, bones, skin and gut)	25	Nil	NA
	15 587	Omena, *Rastrineobola argentea*	30	2 200	110

NA = not applicable

Source: Wananchi Marine Products (K) Ltd, W.E Tilley (M) Ltd and AKEFEMA (pers. comm.)

TABLE 11
Proximate composition of major feed ingredients (percent by weight, as fed basis)

Ingredient	Crude protein	Crude lipid	Crude fibre
Wheat middling	15.0	4.2	7.0
Wheat bran	13.0	3.7	12.0
Maize bran	7.5	6.0	10.0
Maize germ meal, solvent extracted	16.0	1.7	5.5
Maize germ cake, expeller	14.0	14.0	4.3
Maize gluten meal	23.0	5.0	4.0
Molasses (cane)	3.0	-	-
Groundnut oilcake	22.0	14.0	9.5
Soybean oilcake (imported)	45.0	7.5	-
Soybean meal (imported)	50.0	1.4	-
Cottonseed oilcake (imported)	38.0	5.8	18.0
Sunflower seed oilcake (imported)	35.0	14.0	20.0
Rice bran, mechanically extracted	12.0	4.5	-
Brewers dried yeast	45.0	1.2	3.9
Fodder yeast	30.0	-	-
Omena fishmeal	58.0	15.0	0.1
Nile perch fishmeal	53.0	15.0	-
Fishmeal (imported)	58.0	15.0	-

Source: College of Agriculture and Veterinary Sciences, Department of Food Technology and Nutrition (2005, pers. comm.)

TABLE 12
Ingredients of plant and animal origin commonly used as aquafeed in Kenya

Type of ingredients	Form in which fed to fish	Nutritional value	Target fish species
Leaves cassava, arrowroot, sweet potato, *Titonia*	Chopped or whole or added to pellets (dried and ground, inclusion rate of 20–30%).	Excellent source of Vitamins, A, B_1, B_2, C and niacin. Crude protein levels, 4.6%–7.0%. Carotene helps give colour to trout flesh and ornamental fish.	Tilapias, common carp after the leaves have decomposed. Trout to a lesser extent and mainly for carotenoids.
Leaves *Sesbania, Leucaena, Cassia*	Leaves only, seeds are not used as they are toxic.	Good source of vitamins and protein. Inclusion levels: sesbania-26%, leucaena-20%. Also used as fertilizer. The leaves once decomposed make good compost	Mainly tilapias, other fish benefit from the fertilizer effect.
Cereal by-products Maize bran Rice bran Wheat bran	Fed as is or soaked in fresh blood then dried, ground then pelleted. Can be included in pellets at 50–70% depending on quality of main protein source included e.g. fishmeal.	Good energy source; moderate protein. Maize bran-energy 1 424 kJ/g, CP=11%. Rice bran-energy 1 407 kJ/g, CP=10.9%. Wheat bran-energy 1 344 kJ/g, CP=14–17%.	Tilapias, catfishes, carps.
Maize germ	Fed as is or soaked in blood.	Higher protein than bran; good energy source	Tilapias, carps, catfishes.
Wheat pollard	Very finely ground so often included in pellets; inclusion rate depends on main protein source e.g. fishmeal and can be as high as 60–75%. Rarely fed alone as powder.	Good energy source. CP=13.2%	Tilapias, catfishes, carps. Also a major component of trout feeds.
Oilseed cakes Soybean Sunflower Sesame Cottonseed	Cake made by pressing, contain more fats and less protein than cakes made by solvent extraction.	Excellent protein and energy sources. Can get mouldy or become rancid if improperly stored. CP=45–60%, Lipid=1–7%	Tilapias, catfishes, carps.
Animal waste Slaughter-house waste or animal by-products or fish wastes	Can be put directly into pond. Large pieces should be chopped.	Excellent protein and mineral source. Some kind of animal or fish product are usually good if fish are reared in cages. Rich in vitamin B_{12}. CP=48–50% CL=10–14%	Especially for catfishes and also for tilapias and trout.
Insects termites, white ants locusts, maggots, silkworm larvae	Fresh or dried.	Excellent energy source; high protein. Silkworm- CP=55–75%,CL= 15–30%, Termites (dried)-CP=35.7%, Termites(raw)- CP=38%	Trout, tilapias, catfishes, carps.
Industrial waste: Brewers waste	Wet or dried. Can be put directly into pond.	CP=10.7%	Catfishes

CP= crude protein; CL=crude lipid

Source: Veverica, Were and Gichuri (2002)

Farmers in Kenya use a wide variety of supplementary feeds (Table 12) and these also vary by season and region.

3.2 Feed formulations and manufacturing

Compounded pellets in Kenya are only available for rainbow trout and Nile tilapia (Table 13). From 2000 to July 2004, Lafarge Ecosystems (formally Baobab Tilapia Farm) formulated and made their own feeds and then contracted Atta Kenya Ltd. in Mombasa to make a feed based on their formulation. Unga Limited also produces compounded feeds for Nile tilapia but only for orders of not less than one tonne/year (Table 13).

It should be noted that the diets formulated for pigs and poultry are also successfully used as alternate feeds for Nile tilapia and North African catfish, *Clarias gariepinus*, either as single feeds or mixed with Lake shrimp.

TABLE 13
Trout and tilapia pellet production (2004–2005)

Feed	Production (tonnes)		Cost (Ksh/tonne)	
	2004	2005	2004	2005
Trout pellet (Tamfeeds)	45	45	35 000	41 000
Tilapia pellet, Atta Kenya Ltd.		59	17 000	17 000
Tilapia pellet, Unga Ltd. (made-to-order)	*	*	30 000	30 000

*No orders received during the period

Source: Lafarge Eco Systems, Tamfeeds Limited and Unga Limited (pers. comm.)

TABLE 14
Industrial and farm made fish feed formulations in Kenya

Trout pellets (composition not available)	Industrial tilapia pellets	Farm-made tilapia feed (Western Kenya)	Farm-made catfish feed (Western Kenya)	Catfish feed- (Moi University)	Catfish feed (Sagana Fish Farm)
Fishmeal	Wheat pollard 50%	Fishmeal 40%	Lake shrimp 80%	Fishmeal 50%	Lake shrimp 34%
Wheat pollard	Copra cake 17%	Maize meal 60%	Chicken growers mash 20%	Maize germ 15%	Wheat bran 66%
Soybean meal	Cotton seed cake 17%			Cotton seed cake/ sunflower seed cake 9%	
Wheat bran	Fishmeal 16%			Wheat bran 25%	
Calcium carbonate				Vitamins/salt 1%	
Vitamin and mineral premix	Yes	?	?	Yes	Yes

? = information not available

Source: MLFD (2005)

Knowledge of the nutritional requirements of various fish species and technological advances in feed formulation among the feed manufacturers and the fish farmers has increased considerably. Consequently, the development and use of farm-made and formulated feeds to supplement or to replace natural feeds has made rapid strides. Even though it is claimed in some quarters that there is an abundance of feedstuffs and although farmers and hobbyists are now able to formulate their own fish feeds from locally available ingredients, the cost of these ingredients is often prohibitive.

Most plant protein sources, apart from a few like soybean meal, do not comprise more than 25 percent of the diet. Cotton oilseed cake is included at a maximum of 10 percent (though 5 percent is advisable) due to gossypol and other growth inhibitors. Most commercial farms use cooked soybeans, which can be incorporated at levels as high as 42 percent of the diet. Table 14 shows some of the industrial and farm-made feed formulations that are used in Kenya.

Most feeds used in intensive production systems and in home aquaria are commercially produced dry feeds. These consist of simple mixtures of dry ingredients (mash or meal) to more complex compressed pellets or granules. Pellets are often broken into smaller crumbles. The only pellets produced in Kenya are sinking steam extruded pellets for tilapia and trout.

Semi-moist and wet feeds are made from single or mixed ingredients, such as trash fish (though rarely), cooked legumes, rice bran, maize flour, wheat bran, brewers waste, soybeans, cotton and groundnut oilseed cake, bloodmeal, fishmeal or kitchen waste. After cooking they are shaped into cakes or balls, which are then fed to the fish. These feeds are made by a few farmers especially for feeding catfish.

Farm-made feeds are prepared in various ways (Figure 2). Most farmers begin with milling the ingredients, mixing them to desired formulations, adding warm water to make a moist dough and extruding the dough through a meat mincer. The moist "spaghetti" is chopped into small pellets and these are normally sun dried. Other

FIGURE 2
A feed mill for production of farm-made aquafeed, Kirinyaga District, Central Province (left) and a locally assembled pelletizer at the Sagana fish farm, Kenya (right)

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farmers simply mix the dry ingredients and feed their fish with the mash, without further processing. Ingredients are obtained from feed stores, grocery stores and feed stores as well as from various feed manufacturing companies or millers.

3.3 Feeding practices

The basic feed management options employed in Kenya can be grouped into four categories:

1. Zero input systems: The fish are entirely dependent on natural aquatic productivity. This form of aquaculture is carried out by farmers practicing subsistence fish farming (non-commercial small-holder farmers). Yields range between 0.5 and 1.5 tonnes/ha/year. The majority (67 percent) of fish farmers practice this option and contribute about 27 percent of the total aquaculture production in the country.
2. Enhanced primary production systems: In these systems fertilizers are used to increase natural food production. About 75 percent of fish farmers in Kenya fertilize their ponds to some degree or other, either with organic or inorganic fertilizers.
3. Supplementary feed systems: In these systems an external feed is provided to supplement natural productivity. This type of management is practiced by small-scale commercial fish farmers who fertilize their ponds with organic manure and also feed their fish with milled animal feeds (e.g. growers mash, maize, wheat and rice bran or dairy meal). Farmers who practice this option obtain yields of up to 15 tonnes/ha/year.
4. Complete feed systems: Fish are provided with a "nutritionally complete" diet in pellet or moist dough form. Tilapia pellets contain 25 percent protein and 5 percent lipid. Trout grower pellets contain 38 percent protein and starter crumbles have a crude protein content of 50 percent. Production under these conditions varies between 10 and 80 tonnes/ha/year. In intensive systems, tilapia has the advantage in that they can be fed a prepared feed that includes a high percent of plant proteins, while North African catfish requires some fishmeal in the diet for optimal growth. Complete diets are used in all intensive systems (concrete raceways and circular tanks) as well as in recirculation hatcheries. Complete diets are also used under high density cage culture conditions (e.g. Dominion Farms in Western Kenya). Sagana Fish Farm, in collaboration with Moi University, is actively undertaking research on feed formulations using local ingredients.

In intensive systems, fish are fed twice a day (morning and afternoon) but younger fish are fed more frequently. In semi-intensive systems the fish are fed once daily.

TABLE 15
Feeding frequencies, ration and FCR under different culture systems. All fish in Kenya are fed manually

Culture system	Species	Ration	Feeding frequency	FCR
Intensive	Tilapia (Lafarge Ecosystems)	15 kg/day for 8 000 average weight 100 g fish	Every hour, due to flow-through water system	2:1
	Tilapia in cages (Dominion Farms)	2.2 kg/day for 120 kg fish	2 x per day	2.2:1
	Trout	3.5 kg/day for 50 kg of fingerlings 50 kg/day for 1 ton of fish	Fry are fed hourly till satiation. Mature fish are fed 2/day	2:1
Semi-Intensive	Tilapia	Shrimps/maize meal 0.4 kg/day for 25 kg of fish	1x per day	2:1
	Catfish	0.4 kg/day for 20 kg of catfish	1x per day	2:1
	Gold fish	3 kg/day (5 ;000 fishes)	2x per day (morning & afternoon)	-

Source: Lafarge Ecosystems, Dominion Farms Catfish and Tilapia Farmers in Western Kenya (2005, pers. comm.)

Table 15 provides an insight into fish feeding methods in Kenya under different culture conditions.

3.4 Feed storage

Manufactured feeds as well as farm-made feeds with a high lipid and protein content are highly perishable and should be stored under optimal conditions to minimize losses. Only the larger commercial farms have the appropriate infrastructure for bulk storage of feeds or feed ingredients. There is a need to inform smaller farmers of best feed storage practices.

3.5 Review of the development of the animal and aquafeed industries

The most important and recent developments in the feed manufacturing industry has been the formation of the Association of Kenya Feed Manufacturers (AKEFEMA) in 2003 under the umbrella of the Kenya Association of Manufacturers (KAM), which is the country's leading representative industrial organisation. KAM's mission is to promote competitive local manufacturing in a liberalised market.

Currently, there are about 80 active, registered / licensed small and large feed manufacturers, which use about 450 000 tonnes of raw materials. In 2005, the value of the products used by the animal feed industry was estimated at Ksh 6 billion. Omena (*Rastrineobola argentea*) represents about 6.6 percent of the raw materials by volume, which is equivalent to approximately 30 000 tonnes.

There are 17 large feed manufacturers in Kenya. The feed manufacturers declined to provide the necessary information on the capacity of feed production as they considered this to be confidential and so the exact capacity of feed manufacturers could not be established. Total animal feed production in Kenya during 2004/5 was 466 151 tonnes, with poultry feed comprising 55 percent, pig 7 percent, cattle concentrates 35 percent and 3 percent others such as pet, horse and rabbit feed (see Table 16 for the proximate composition of the major animal feeds).

The "fishmeal-based" animal feeds industry in Kenya was developed

TABLE 16
Proximate composition of the major animal feeds in Kenya

Feed	Composition		
	Crude protein	Crude lipid	Crude fibre
Chick & duck mash/crumbles	18.0	6.0	6.0
Growers mash/pellets	15.5	5.0	6.0
Layers complete meal/pellets	17.0	6.0	6.0
Broiler starter mash/crumble	18.8	7.0	5.0
Broiler finisher mash/pellets	17.5	5.0	4.5
Sow & weaner meal/cubes	17.5	4.5	6.5
Pig finishing meal	15.0	6.0	6.5
Calf early weaner pellets	17.0	5.0	6.5
Young stock meal/pencils	16.0	5.0	6.0
Dairy meal/cubes	15.0	4.0	6.5
Unga tilapia pellet	25.0	5.0	6.0
Tamfeeds trout crumble	50.0	12.0	-
Tamfeeds trout pellet	38.0	9.0	-

Source: College of Agriculture and Veterinary Sciences, Department of Food Technology and Nutrition (2005, pers. comm.)

during the last 10 years. This has generated an unprecedented demand for the second most important commercial fish species in Lake Victoria, whole omena and its dust are used in animal feed production whereas the skeleton of Nile Perch is used for fishmeal production. The development of the animal feeds and fishmeal industry has drastically reduced the quantity of whole omena and skeleton of Nile perch available for human consumption. In a 1997 survey, Abila and Jansen (1997) found that six animal feed manufacturing companies in Kenya were using about 70 percent of the omena catch to manufacture fishmeal, while another two companies were using 60 percent of all Nile Perch skeletons available within the Lake region for fishmeal. This is in sharp contrast to the early 1990s when the entire omena catch was used for human consumption.

The demand for local fishmeal by the animal feed industry cannot be met. This is because the omena and Nile perch fishmeal are high in protein and significantly cheaper than imported fishmeal. It is obvious, therefore, that more and more of the Nile perch skeletons and omena and perhaps other fish products are finding their way into the animal feed industry.

As mentioned previously, only two aquaculture feed lines are commercially manufactured in Kenya. The tilapia pellet is manufactured as a dry 3 mm pellet using a commercial steam pelletizer (capacity 4 tonnes/hour) and an indoor pellet drier. Approximately 58.8 tonnes of tilapia pellets were produced by Atta Kenya Ltd. during 2005 (4.9 tonnes/month), with an ex-factory price of Ksh 17/kg). The trout starter crumble and grower pellet is manufactured by Tamfeeds Ltd. for use on its own trout farms and for sale to other trout farmers in Kenya. The feed is produced as a moist pellet using a simple motorized meat extruder and dried outdoors; the pellet is composed of local ingredients (see Table 14). Approximately 45 tonnes of dry trout feed was produced by Tamfeeds Ltd. during 2005 (at an ex-factory price of Ksh 41/kg. In 2005, a total of 104 tonnes of aquafeeds were produced by the formal feed sector. Given that catfish farming is growing rapidly there is a need for the industry to develop a feed for this species.

Currently, there are no quality standards and the industry is largely unregulated. However, this problem is now receiving the necessary attention. Feeds are basically formulated on biological and economic considerations only.

4. CONSTRAINTS TO SUSTAINABLE AQUACULTURE DEVELOPMENT

Regional availability and accessibility of feed ingredients

Fishmeal is more readily available in the Lake Victoria region than in other areas, whereas wheat bran is more readily available in some parts of the Rift Valley and Central Province, than in other regions. Farm-made feeds are also not readily available and industrially manufactured tilapia and trout feeds are only available in Nakuru and Nairobi. High transportation costs put many feed ingredients and feeds beyond the means of the majority of fish farmers in Kenya. Commercially manufactured diets and high protein ingredients such as

Omena and oilseed cake are too expensive for small-scale farmers. At present many potential feed resources still remain unexplored in Kenya. These include abattoir wastes (meat, bones, blood, hair, feathers, gastro-intestinal tracts, rumen contents), sugar cane factory wastes (bagasse), coffee processing wastes (coffee pulp), and occasionally corn mill sweepings.

Storage

Facilities for the storage of feeds or ingredients are generally inadequate on small-holder farms, either due to lack of knowledge or resources, resulting in a high degree of spoilage.

Feeding

Feed application rates are highly variable. There is also lack of consistency in feeding. Feeding rates are not adjusted regularly as required.

Demand

The current estimated annual production of just over 1 000 tonnes of fish probably explains the undeveloped state of the aquafeed industry. Assuming a feed conversion ratio of 2.5:1, only 2 500 tonnes of feed would be required per annum. This is approximately 0.5 percent of current national animal feed production and is too little to justify any significant investment. Opportunities to develop the aquafeed industry are technically determined by the rate of development of aquaculture itself.

Farm-made feeds tend to be of variable quality, depending on availability of by-products on the market or from the farm. Overall, feed remains one of the biggest obstacles for the expansion of aquaculture in Kenya, especially in medium- and large-scale production systems. Unless affordable feeds can be provided, farm-raised fish products cannot compete with those from marine and inland capture fisheries. In conclusion, there are significant challenges with respect to the availability of feed ingredients and feeds, accessibility, quality, and quantity that impede the development of the sector.

5. RECOMMENDATIONS FOR IMPROVED UTILIZATION OF FERTILIZER AND FEED RESOURCES

- The government must provide an enabling legislative environment for the sustainable and responsible development of the aquaculture sector.
- There is an urgent need for increased collaboration within and between the private and public sectors engaged in aquaculture development activities, including research that addresses aquaculture feed technology and applied nutrition.
- The Livestock Feeds Bill needs to be finalized by the Department of Livestock Production to facilitate the development of high quality aquafeeds.
- The dissemination of information to enhance supplementary feeding methods and appropriate feed storage must be improved.
- Training of technicians in feed technology and nutrient application.
- Farmers with limited cash resources should be trained and encouraged to use low-cost agricultural by-products such as abattoir wastes, mill sweepings and rice bran.
- Surveys of available feed resources should be undertaken on a district basis. This information can be used to assist farmers to develop their own feeding strategies that will lead to improved fish production and optimal use of agricultural by-products within the region.

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