Analysis of feeds and fertilizers for sustainable aquaculture development in Uganda

J. Rutaisire
Department of Wildlife and Animal Resources
Makerere University, Kampala
Uganda

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SUMMARY

This paper reviews the current status of feed and fertilizer use in aquaculture in Uganda. Aquaculture in Uganda is still largely at a subsistence level despite having been practiced for more than 50 years. However, there have been some significant changes since the late 1990s. Sixteen species have been tested for farming in Uganda, but only four (Nile tilapia *Oreochromis niloticus*, redbelly tilapia *Tilapia zillii*, common carp *Cyprinus carpio* and North African catfish *Clarias gariepinus*) are cultured. These species are reared mainly under polyculture conditions in earthen ponds. Monoculture is restricted to North American catfish fingerling production, which are used as live bait in the Nile perch, long line fishery in Lake Victoria.

The majority of small-scale subsistence farmers rely on organic fertilization of ponds and the provision of green leafy materials regardless of whether the fish are herbivorous or not. Cattle and pig manure are available free of charge, whilst chicken manure is available at a relatively cheap price. Supplementary feeds are normally provided by broadcasting the feed, such as rice or maize bran, over the pond surface. All commercial and emerging commercial farmers feed their fish according to specific protocols. Commercial farmers make their own feeds and some produce their own pellets. Commercial fish feeds are not readily available. Only one feed producer makes a sinking pellet, the performance of which still has to be evaluated.

Availability and price of feed ingredients is determined by the agricultural calendar. Transport costs are high, and this affects feed prices. The proximate composition of local feed ingredients is known. Fishmeal is not imported into Uganda and the bulk of the fishmeal is made from the pelagic minnow (silver cyprinid *Rastrineobola argentea*), the second most important commercial fish species in Lake Victoria The country's climate and soils favour large scale production of soybeans and this should be strongly promoted.

On the whole, the major constraints facing the development of the aquafeed industry include the lack of prerequisite information, appropriate technologies, affordable credit facilities and poor infrastructure. However, the current positive trends in aquaculture development, exhibited by substantial private sector investment and an enabling policy framework are indicative of the viability and potential of aquaculture in Uganda.

1. OVERVIEW OF AQUACULTURE PRACTICES AND FARMING SYSTEMS

Aquaculture in Uganda began in 1953 with the establishment of the Kajjansi experimental station of Aquaculture Research and Development Centre (ARDC). Despite its long history the sector has largely remained at a small-scale, subsistence level. The contribution by aquaculture to national fish supply is insignificant. There are approximately 7 152 fish farmers in Uganda with about 30 000 ponds (UBOS, 2004). The average pond size is 222 m^2 and average production has been estimated at 1 800 kg/ha/year (NARO-MAIIF, 2002). Total fish production in 2003 was 5 500 tonnes (FAO, 2005). However, since the late 1990s aquaculture in Uganda has changed rapidly due to the greater interest and participation by the private sector. Several commercial fish farms are emerging in the country and these are targeting the regional table fish market as well as the baitfish market. This is in line with the Government's Plan for Modernisation of Agriculture (PMA).

The recent renewed interest in aquaculture is mainly attributed to the advances in North African catfish *(Clarias gariepinus)* culture. Due to its desired qualities the African catfish has become one of the key aquaculture species in Uganda and is likely to become the main contributor to aquaculture production both in terms of volume and value. Polyculture of North African catfish with Nile tilapia (*Oreochromis niloticus*) has also resulted in the production of larger size fish. The size of table fish is very important in Uganda, since fish of less than 300 g are shunned by the consumers. The aquaculture potential of several fish species has been tested at ARDC, Kajjansi and other parts of Uganda but only a few are cultured in the country (Table 1).

TABLE 1
Fish species that have been tested and their current culture status in Uganda

Species	Not currently cultured	Cultured	Remarks
Nile tilapia, *Oreochromis niloticus*		✔	Widely cultured
Victoria tilapia, *Oreochromis variabilis*	✔		Not currently cultured
Wami tilapia, *Oreochromis urolepis hornorum*	✔		Hybridized & disappeared from ARDC, Kajjansi
Blue tilapia, *Oreochromis aureus*	✔		Disappeared from ARDC, Kajjansi
Oreochromis spilurus	✔		
Oreochromis leucostictus	✔		Considered a wild species that contaminated cultured cichlids.
Redbelly tilapia, *Tilapia zillii*		✔	Herbivorous cichlid cultured widely but often stunts in ponds.
Redbreast tilapia, *Tilapia rendalli*	✔		Imported for hybridization experiments at ARDC, Kajjansi but disappeared from the station
Common carp, *Cyprinus carpio*		✔	Cultured and popular in the cooler mountainous parts of the country.
Grass carp, *Ctenopharyngodon idella*	✔		Failed to breed/disappeared from ARDC, Kajjansi
Giant gourami, *Osphronemus goramy*	✔		Bred on their own in ponds but disappeared
Black bass, *Micropterus salmoides*	✔		Did not breed and disappeared from ARDC, Kajjansi
Semutundu, *Bagrus docmak*	✔		Research to breed & culture in captivity on-going
North African catfish, *Clarias gariepinus*		✔	Cultured and popular
Rainbow trout, *Oncorynchus mykiss*	✔		Not cultured but is caught in Mt. Elgon rivers.
Crayfish, *Procambarus clarkii*	✔		Burrows and destroys pond banks. It has therefore been discouraged in aquaculture. It was introduced into Lake Bunyonyi, a crater lake where it supports a fishery.

ARDC=Aquaculture Research and Development Centre
Source: Owori-Wadunde (2001)

NARO-MAAIF (2002) survey revealed that 50 percent of small-scale fish farmers in Uganda make special preparations prior to stocking their ponds. These include draining and drying the ponds to allow mineralization of the accumulated organic matter. The drained ponds are usually de-silted or dredged. A small proportion of farmers (3 percent) lime their ponds. Fourty percent of the ponds are operated on a flow-through system. The majority of fish farmers (70 percent) rely on ground water for filling their ponds. Most farmers mow the grass both on and around pond dykes and protect their ponds from predators and theft. Most subsistence farmers use a mix of species in an unmanaged manner), with stocking densities ranging from 1–3 fingerlings/m^2 (NARO-MAAIF, 2002).

More recently commercial farms, which practise both poly- and monoculture, have started to emerge. Polyculture is mainly undertaken with North African catfish and Nile tilapia in a predator-prey relationship. This has been made possible by the ready availability of seed of both species. Rutaisire (2005) found that the average fish stocking density in African catfish/Nile tilapia polyculture systems is 10 fish/m at a ratio of 6:4, respectively. Monoculture of Nile tilapia is not popular due to its precocious breeding habits and stunting. Monosex culture of Nile tilapia is yet to be developed and promoted in Uganda. Monoculture is mainly practiced with common carp *Cyprinus carpio*, especially in the mountainous cooler regions of the country where temperatures fall below 20ºC. Overall, 57 percent of fish farmers practice polyculture (Nile tilapia and African catfish) and 43 practice some sort of monoculture (NARO-MAAIF, 2002). The production of African catfish fingerlings is increasing, particularly for live-bait in the Nile perch long line fishery in Lake Victoria. During the last three to four years, 11 farmers began producing African catfish fingerlings as a major business activity, with an estimated production of 500 000 fingerlings per month. The live fish are packed in jerry cans or buckets and transported in pick-up trucks to fishermen at the lake.

The price of the baitfish (average total length 10 cm) ranges from US$0.06 in the dry season to US$0.17 per fingerling in the wet season. These farmers have constructed hatcheries with all the necessary tanks for induced spawning, stripping, egg incubation, hatching and fry rearing (14–21 days). Fry from the hatcheries are grown in concrete tanks, at densities of up to 2 500/m^3, or plastic lined ponds and raised to baitfish of 10 cm or larger. Cage culture of catfish under commercial conditions is currently being tested by the USAID (United States Agency for International Development)/Uganda Fisheries Investment for Sustainable Harvest (FISH) project.

TABLE 2
Estimated national and regional annual yield and value of major cultured fish species

Region	Species	Fish production (kg/ha/year)	Price (US$/kg) (1999/2000)
Central	Tilapias (*O. niloticus* and T. zilli)	276	1.60
	North African catfish	350	1.10
	Common carp	71	1.10
Eastern	Tilapias (*O. niloticus* and *T. zilli*)	625	1.60
	North African catfish	417	1.60
	Common carp	532	1.50
Northern	Tilapias (*O. niloticus* and *T. zilli*)	588	1.70
	North African catfish	432	1.10
	Common carp	69	1.10
Western	Tilapias (*O. niloticus* and *T. zilli*)	972	1.50
	North African catfish	140	0.90
	Common carp	297	0.80
West Nile	Tilapias (*O. niloticus* and *T. zilli*)	889	1.60
	North African catfish	-	1.65
	Common carp	374	1.60
National Average	Tilapias (*O. niloticus* and *T. zilli*)	646	1.60
	North African catfish	406	1.10
	Common carp	333	1.10

*Price per kg fish is based on the market price not ex-farm gate price, which may be much lower.
US$1.00 = Uganda Shilling (USh) 1 820 (average exchange rate, 2005)

Source: NARO-MAAIF (2002)

In general, there is a lack of accurate production data from small-holder ponds. This is because farmers do not keep records. However, some estimates were obtained by the NARO-MAAIF (2002) baseline survey and these are summarised, on a regional basis, in Table 2. For the most commonly cultured fish species (*O. niloticus, C. gariepinus* and *C. carpio*) the current production level was estimated at 13.8 kg/100 m^2/year, which is significantly better than the historical records of 0.7 to 7.1 kg/100 m^2/year (Owori-Wadunde, 2001). More recent production data were not available at the time this report was compiled.

2. ANALYSIS OF FERTILIZERS, FEEDS AND FEEDING

2.1 Availability and accessibility of manure and inorganic fertilizers

Fish farming in Uganda mainly consists of mixed species "polyculture" in organically fertilized ponds. This is because the majority of fish farmers are poor, small-holder farmers who keep livestock and grow crops (Isyiagi, 2004). Approximately 58 percent of fish farmers use cattle manure to fertilize their ponds, while others used chicken, goat, pig and duck manure, coupled in most instances (40 percent) with compost cribs that are filled with grass, kitchen wastes and farm by-products such as cabbage stumps. Chicken manure was used least often due to the high price and competition with crop farming (NARO-MAAIF, 2002). Chicken manure is available from commercial poultry farmers at US$16.50 per tonne (Mr. Tugumisisrize, Sunfish Farms Ltd., pers. comm.), which makes it unaffordable for most small-scale farmers. Pig and cattle manure are free. Organic manure is generally applied at approximately 20 kg/100 m^2. Further application depends on the "greenness" of the pond. Manure is available throughout the year and more than 80 percent of farmers have access to organic fertilizers, although not in sufficient quantities. Most small scale farmers fertilize their ponds using manure swept from livestock enclosures. Approximately 40 percent of the farmers install cribs in their ponds and these are filled with grass, kitchen wastes, animal manure and farm by-products such as cabbage stumps. The rate of refilling the cribs depends on the colour of the water which they monitor visually.

Inorganic fertilizers are rarely used in Ugandan aquaculture. However, there are some farmers who use di-ammonium phosphate (DAP) and nitrogen phosphate potassium (NPK) in catfish nursery ponds. DAP is applied at the same time when the fry are introduced to the nursery ponds. It is dissolved in water and applied at a rate 0.5 kg/100 m^2. NPK is used at the same rate. Inorganic fertilizers are readily available in agricultural shops. A combination of phosphoric acid and urea has been reported used to sustain plankton growth in ponds (Mr. Tugumisisrize, pers. comm.). The mix consists of 50 l of phosphoric acid and 5 kg of urea, which is applied to 7 000 m^2 ponds every 2–3 weeks. According to the manager of the farm this treatment results in sustained plankton production, dominated by cladocerans and lesser quantities of rotifers and copepods. In 2005, the price of chemical fertilizers ranged from US$430–500/tonne.

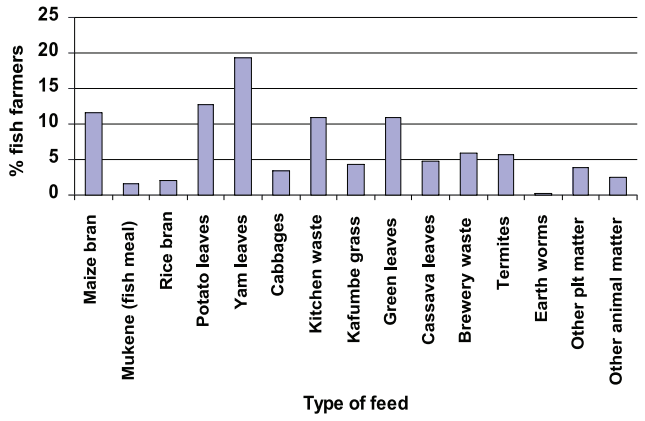
2.2 Availability and accessibility of feed ingredients

A multitude of ingredients are used as fish feeds in Uganda. These include vegetables, grass, cereals, cereal brans, oilseed cakes, industrial and kitchen wastes, insects and fishmeal. The proportional use of these ingredients is illustrated in Figure 1. Availability of most of these feed ingredients is seasonal. Cereals are readily available and cheap at harvest time, but prices gradually increase by the time the next harvest comes around.

Maize

Uganda harvests two maize crops per year with a total production of approximately 500 000–600 000 tonnes (Table 3). For more than a decade Uganda has been exporting 50 000–100 000 tonnes of maize per annum to Kenya through informal trade (Magnay,

FIGURE 1
The proportional use of different types of feeds by Ugandan fish farmers



Source: ARDC, Kajjansi database (pers. comm.)

2004). Relief agencies also purchase approximately 100 000 tonnes per year for the region and Uganda also supplies maize to Tanzania and Rwanda.

The price of maize in Uganda is high and this is because of the substantial volumes that are exported or bought by relief agencies. The average price of maize and maize bran, for the period January to October 2004 was US$0.28/kg and US$0.08/kg, respectively.

Rice

Domestic rice production in 2005 was estimated at 51 917 tonnes (Table 4). This is not adequate to meet the local demand and in 2005 Uganda imported an additional 40 538 tonnes.

TABLE 3
Estimated maize production and trade (tonnes) during 2001–2004

Year	Production (tonnes)	Internal demand	Relief agencies	Export		Surplus
				Formal export	Informal export	
2001	550 000	400 000	50 000	10 000	40 000	50 000
2002	530 000	400 000	50 000	20 000	60 000	0
2003	580 000	400 000	100 000	_	80 000	0
2004 (drought)	530 000	350 000	80 000	20 000	80 000	0
2005 (projections)	600 000	400 000	60 000	30 000	60 000	500 000

Source: Uganda Grain Traders Ltd. (pers. comm.)

TABLE 4
Trends and projections in rice market volumes (tonnes)

	2003	2004	2005	2006	2007	2008	2009	2010
Total rice demand	88 000	90 200	92 455	94 766	97 136	99 564	102 053	104 604
Domestic production	48 000	49 920	51 917	53 993	56 153	58 399	60 735	63 165
Import	40 000	40 280	40 538	40 773	40 982	41 165	41 318	41 440

Source: Spilsbury *et al.* (2004) and author's estimate based on survey findings

The price of rice varies seasonally, ranging from US$0.41–0.44/kg, and is linked to the main harvest times. Rice bran is increasingly used to feed fish and costs less than maize bran.

Kitchen and bakery waste

Kitchen waste is obtained from homes and public eating places such as restaurants, hotels and schools. However, most kitchen waste is collected as pig feed. During the farm visits carried out by the author, it was found that some farmers were feeding fish on waste bread from bakeries in Kampala and in some instances this constituted over 50 percent of the feed. In most instances kitchen and bakery wastes were obtained free as a way of disposal.

Mill sweepings

Farmers in the neighbourhood of feed or flour mills collect the floor sweepings, which they use as feed. Sweepings are of various types, e.g. millet, cassava, sorghum, maize or a combination of all of these. The volume of sweepings produced in the country is not known. Sweepings are obtained free of charge.

Abattoir by-products and waste

Bloodmeal is the principal abattoir by-product and is used for making fish and livestock feed. However, most of the abattoirs are located in urban areas and most farmers are unable to transport the product to their farms. About 400 tonnes of bloodmeal are produced around Kampala. The amount produced in the northern part of Uganda is not known. The price of bloodmeal is US$0.33/kg and no recent changes in volume and price have been reported.

Termites / white ants

According to Isyiagi (2004) some farmers feed their fish on termites, which are either collected by the farmer or purchased from collectors at a cost of US$0.27/kg, during the periods March/April and August/September. The quantity obtained depends on the number and size of anthills on the farm, moonlight intensity and type of white ant. On average, an anthill yields approximately 50 kg per annum.

Oilseed cakes

Cotton and sunflower oilseed cakes are the two major cakes used as fish feed in Uganda. They are purchased from trading centres and major distributors in urban areas. The price of oilseed cakes varies seasonally. Oilseed cakes are used by industrial feed mills as well as small, backyard feed mixers, commonly referred to as *Kitiyo* (literally meaning those who use a spade to mix feeds). Oilseed cakes are not used for human consumption.

Brewers waste

Brewery waste is obtained from local sorghum breweries and from the industrial lager breweries. The wet product (fermented barley and sorghum) is used as a fish and a livestock feed. It was estimated that the two industrial breweries produce around 22 568 tonnes of waste per annum. Brewery waste is sold at US$5.50 per tonne at the factory gate; while the cost to the end user (farmer) is US$11 per tonne. Local brewery waste is available throughout the year.

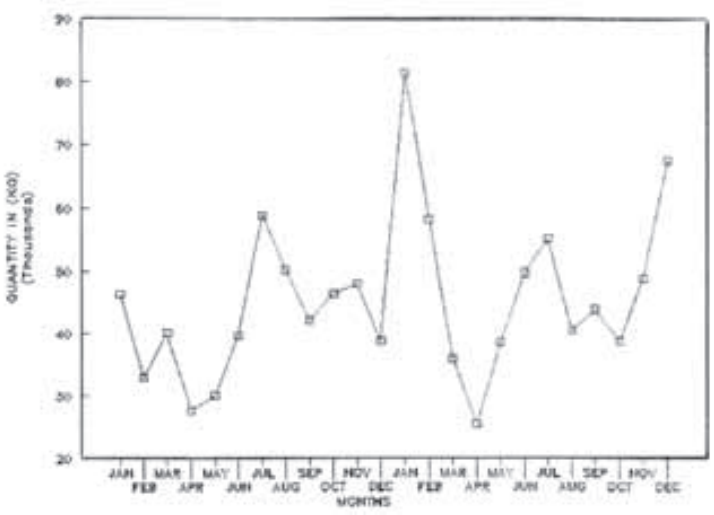
Green leafy material

Green leaves are readily available throughout the year in most parts of the country. Nelly (2004) found that farmers use green leaves as a fish feed regardless of whether the fish are herbivorous or not. The most widely used leaves are cocoa-yam, sweet potato, Kafumbe grass (*Galisoga pariflora*) and Kanyebwa grass (*Oxalis latifolia*).

Fishmeal

The pelagic minnow silver cyprinid, mukene or dagaa omena (*Rastrineobola argentea*) is the most important local species for the manufacture of fishmeal, but is also an extremely important source of fish for human consumption. This is similar to the situation in Kenya and Tanzania. Monthly landings of *R. argentea* show two peak periods (Wandera, 1993; Wandera, pers. comm., 2005), December to January and a minor peak in July and August (Figure 2). It is readily available all year around, though prices increase in April and May and in October when catches are low. Catch surveys show that the yearly average catch in Uganda is approximately of 90 372 tonnes. The fish are sun dried and milled and sold at US$0.47 /kg. It is important to note that fishmeal is not imported into the country. Emerging commercial fish farmers use the fish together with other ingredients such as maize, rice bran to produce farm-made feeds. However, the fishmeal is improperly processed and handled. Samples of mukene fishmeal taken at fish markets and discussion with users indicated that it is almost always contaminated with sand. Some of the users believe that sand is added deliberately by the vendors to increase the weight of the fishmeal. To avoid contamination, some of

FIGURE 2
Monthly landings of silver cyprinid *Rastrineobola argentea* at Masese, 1990–1991



Source: Wandera (1993)

the emerging commercial farmers now buy fresh *R. argentea* directly from the fishers, which they then dry on the farm using locally made driers.

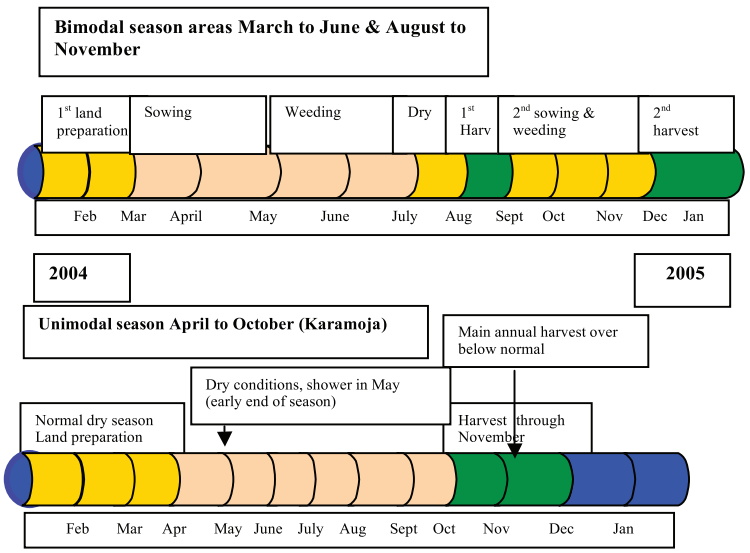
Vitamins & minerals

All vitamin and mineral premixes are imported and are readily available in veterinary drug shops throughout the year. The cost ranges from US$17.63–$22.04 per kg. Raw materials for minerals such as cattle horns, fresh water snail shells are readily available in the country and these products cost around US$2.80 per kg.

The agricultural calendar

The agricultural calendar determines the availability and price of commodities. Uganda has two agricultural seasons. One describes the situation in the bi-modal rain areas, while the other focuses on the unimodal rain regions (Figure 3). The main ingredient in animal feeds in Uganda is maize. Quite often there is a scarcity of maize on the market (mainly during the period June to October) due to several factors, including the demand from neighbouring countries and relief needs by WFP, amongst others. This results in large price increases in the informal market (Magnay, 2004) and also leads to seasonal price fluctuations of local animal feeds.

FIGURE 3
Uganda agricultural calendar



Source: FEWS (2004)

2.3 Nutritional composition of feed ingredients

The proximate composition of the available conventional and non-conventional feed ingredients is shown in Table 5. Most of the farm by-products used as fish feed in Uganda have a low protein content. Silkworm pupae have only recently been processed and used for feeding of North African catfish brood stock. According to the farmer the results are encouraging but unfortunately not yet quantified.

2.4 Price, transportation and storage of feed ingredients

The cost of feed ingredients varies with the agricultural calendar and by region. Table 6 shows the range of prices for the commonly used feed ingredients.

TABLE 5
Proximate composition of local feeds and feed ingredients commonly used as aquafeeds (% dry matter)

Feed/ingredients	DE (kcal/g)	DM	CP	CL	Ash	CF	NFE	P	C
Ants/termites	-	-	36.0	1.1	-	-	-	-	-
Barley	3 274	88.0	10.6	2.4	-	4.5	-	0.4	0.1
Blood meal	2 981	87.6	60.5	2.3	25.5	0.0	11.7	0.1	0
Brewers waste	-	-	27.8	12.6	-	-	-	-	-
Broken maize	1 900	85.0	12.0	4.0	-	7.5	-	0.4	0.3
Cassava	3 188	88.0	2.5	-	-	4.5	-	0.1	0.2
Cassava leaves	-	-	25.8	15.2	-	-	-	-	-
Coco-yam leaves	-	-	19.5	17.8	-	-	-	-	-
Cotton seed cake	2 422	94.0	41.1	6.2	7.9	6.2	38.0	0.5	0.1
Cotton seed oil	9 000	68.6	-	99.5	-	-	-	-	-
Fishmeal (*Alectes jacksoni*)	3 400	90.0	62.0	8.2	-	0	-	3.0	4.9
Fishmeal (gomba)	2 800	90.0	39.0	15.0	-	0	-	4.0	7.0
Fishmeal (*R. argentea*)	3 402	93.1	60.9	10.3	-	0	-	2.3	2.5
Kafumbe grass (*Galisoga pariflora*)	-	-	22.4	14.9	-	-	-	-	-
Maize	3 593	85.0	8.8	3.9	-	2.1	-	0.4	0.3
Maize bran	-	87.2	6.9	5.8	1.6	7.5	85.7	0.4	0.02
Cane molasses	1 800	-	4.0	-	-	-	-	0.1	0.7
Rice bran	-	-	10.1	18.3	-	-	-	-	-
Rice hull	1 950	89.9	7.0	1.0	-	20.0	-	0.5	0.03
Sesame cake	3 337	89.5	38.5	9.0	-	4.0	-	0.9	1.7
Silkworm pupae meal	-	-	52.1	15.5	7.2	2.9	22.1	-	-
Soy cake, pressed	2 900	87.0	43.0	1.8	-	6.5	-	0.7	0.3
Soybean, whole	4 241	90.0	36.0	18.8	-	5.8	-	0.5	0.2
Sunflower cake, pressed	2 086	88.0	25.0	10.2	-	22.0	-	1.0	0.3
Sunflower oil cake	-	94.8	41.7	12.9	4.6	16.5	30.8	4.6	0.2
Sweet potato	3 440	87.5	3.8	0.7	-	2.7	-	0.2	0.1
Sweet potato leaves	-	-	20.4	15.9	-	-	-	-	-
Wheat bran	-	79.6	14.6	-	-	10.5	-	-	0.1
Wheat flour	3 441	88.0	12.0	2.0	-	2.0		0.4	0.3
Wheat pollard	1 450	90.0	13.0	4.0	-	7.0		0.4	0.1

DE= digestible energy, DM= dry matter, CP = crude protein, CL = crude lipid, NFE = nitrogen free extracts, P = phosphorus, C= calcium

Source: Apolot (2003); Isyiagi (2004)

At the peak of the harvest season commodity prices tend to be lower and then increase with demand and decreasing supply. The cost of fishmeal also fluctuates seasonally. It is lower during January and February and higher from March to May (Table 6) due to lower catches during this time of the year.

Transportation of feeds and feed ingredients takes various forms including carrying the sacks on people's head, bicycles and trucks. Some villages or trading centres have mills where cereals are processed for food, leaving behind bran which is used to feed livestock and fish. Bran from the

TABLE 6
Production and price of various feed ingredients

Ingredients	Annual production (tonnes)	Annual price range (US$ per kg)		
		Mean	Minimum	Maximum
Sesame seed cake	1 000	0.14	0.11	0.19
Cotton seed cake	12 000	0.14	0.08	0.17
Sunflower cake	5 000	0.11	0.10	0.14
Groundnut cake		-	-	-
Maize bran	-	0.080	0.07	0.09
Fishmeal	-	0.385	0.1	0.67
Cotton seed cake	-	0.017	0.014	0.02
Shells (mineral)	-	0.090	0.09	0.09
Vitamin premix	-	5.560	5.56	5.56
Soybean cake	-	0.500	0.44	0.56
Blood meal*	400	0.420	0.42	0.42
Snail shell	-	0.095	0.08	0.11
Bone meal	-	0.190	0.19	0.19

* This figure is for the Kampala district

Source: Mutima Best Quality feed dealers, Kisenyi, Kampala (pers. comm.)

FIGURE 4
Loading and off loading of feeds and feed ingredients from and to trucks ready for transportation

mills in urban centres is packed in 100 kg bags and transported by traders from all over the country in trucks while loading and offloading the trucks is done by hired labourers (Figure 4). The cost of transportation is US$1.11 km/tonne.

In the past rural people in Uganda stored and preserved food in traditional granaries. Cereals or dried cassava were kept in such granaries for years without loss. Unfortunately this practice is disappearing. Farmers now sell their produce immediately after harvest and store very little of it for later use. This practice is based on the need for school fees and other requirements and a false sense of security that food can always be bought. The country does not have silos or other facilities for storing enough food for the population for any length of time. Fortunately, Uganda is blessed with two rainy seasons; hence prolonged dry seasons are uncommon.

The lack of adequate storage facilities is a major constraint to growth of the aquaculture sector in rural areas, because farmers cannot purchase ingredients when prices are low and store them for use later in the year. With the emergence of commercial fish farming it is hoped that farmers will construct proper feed stores. This initiative is being spearheaded by the FISH project, which has already selected model farmers on condition that they have or will construct feed stores.

2.5 Feed formulation and manufacturing

Feed formulation depends entirely on the availability of ingredients and their cost. Commercial fish farmers combine feedstuffs in various ways. For example, some emerging commercial fish farmers mix 70 percent maize bran and 30 percent fishmeal or sunflower or cotton oilseed cake. The ingredients are pounded or milled, mixed at the required proportions (when adequate quantities are available) and broadcast over the surface of the pond. Some farmers moisten the mixture to minimise loss by wind dispersal, while others mix the feed ingredients and cook the mixture to make a cake. In other instances, hot water is added to the formulated mixture and kneaded into dough that is passed through a meat mincer to make "spaghetti" (Figure 5a). The "spaghetti" is dried on corrugated iron or plastic sheets (Figure 5b) or in solar driers (Figure 5c & d). For fish fry the dried "spaghetti" is blended and sieved using mesh sizes of 200 µm and 350 µm. The pellets tend to remain stable in water for some time and hence loss into the pond bottom is minimized. Commercial catfish hatchery owners formulate a starter diet consisting of 5 kg of fishmeal, 3 kg of whole soybean flour and 2 kg of whole

FIGURE 5
Feed processing and drying (a) feed pelleter (b) direct sun drying on corrugated iron sheet (c) solar dryer (d) improved solar dryer

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maize flour and five eggs. However, Aquafarm and Umoja farmers follow the recipe recommended by Hecht, Uys and Britz (1988) (visit www.ru.ac.za/academic/departments/difs for further details).

Only one company in Uganda produces a sinking pellet. The process involves milling the ingredients, formulating, mixing and steam pelleting (77°C) and fat injection, cooling (25°C) and bagging. The pellets are produced in two sizes, 2 mm and 3 mm and have a water stability of around 45 seconds. The installed production capacity for pellet production is five tonnes per hour but only a few tonnes are produced upon request. This is mainly due to a lack of demand and the hesitancy by the producer to store feeds. The company is now cooperating with the FISH project to produce an extruded diet.

FIGURE 6
Pond attendant feeding cat fish fry reared in a plastic lined nursery pond

2.6 Feeding practices

The main herbivorous fish produced by small-scale, subsistence farmers is *Tilapia zillii* and it is mainly fed on coco yam and potato leaves or on Kafumbe grass (*G. pariflora*) and Kanyebwa grass (*O. latifolia*). Most green vegetable feeds are either chopped or presented whole to the fish. There is on-going research to determine optimum conditions for polyculture of *T. zillii* with *C. gariepinus*. Most small-scale farmers do not feed their fish at regular intervals but do so depending on availability of material and when they have time. According to Nelly (2004), 22 percent of small-scale farmers do not feed their fish at all, 46 percent feed daily, 10 percent feed once a week, 9 percent feed several times a week, 4 percent feed fortnightly and 9 percent feed their fish irregularly. The leaves are tied together and simply thrown into the pond. The fish eat off the leaves leaving the stalks, which are removed by the farmer.

The major commercial aquaculture species are *O. niloticus* and *C. gariepinus* and the main feeds for these species are maize bran, cotton and sunflower oilseed cake and fishmeal. Commercial farmers feed their fish with pellets, steamed oilseed cake or dry mash. Pellets and powder/mash are broadcast over the pond or tank surface regardless of the species or culture system (Figure 6), whilst the steamed oilseed cakes are presented on feeding trays. There is no information on FCRs of the farm-made feeds.

On commercial farms, fry are fed at 15 percent of body weight per day, decreasing to 6 percent and below towards the end of the culture cycle. Feeding frequencies vary between farmers and by region, but normally fish are fed twice daily. The major problem is that most farmers do not know the biomass of fish in the ponds and cannot therefore determine appropriate rations.

Despite the recent advances, the development of aquaculture in Uganda is constrained by the absence of good commercial feeds and a lack of technical know-how to make appropriate farm-made feeds. Emerging commercial fish farmers have therefore had no option but to haphazardly formulate feeds on their farms. During 2005, a number of commercial fish farmers resorted to importing feed from a South African company (Aquanutro (Pty) Ltd.), for catfish fingerlings. Other foreign feed companies are now also showing interest in supplying catfish producers with formulated feeds.

2.7 Labour costs

Labour is available in most parts of the country, though it is largely unskilled. Labour costs are highly variable (most expensive in urban areas and cheapest in rural areas). The cost of hiring unskilled labour in Kampala is US$2.70 per day, but decreases with distance from the city.

3. THE ANIMAL FEED INDUSTRY IN UGANDA

As mentioned previously, there are no industrial aquafeed manufacturers in Uganda. What is presented below pertains to the general animal feed industry, which started in the late 1960s. The earliest feed company was registered in 1967. Currently there are about 28 industrial and small-scale feed manufacturers in Uganda. Currently, some 80 000 tonnes of animal feeds are produced by all large and small-scale mills (*Kitiyo*), of which 85 percent (68 000 tonnes) comprises poultry feed. The small mixers account for 60 percent of the production. However, inadequate services (delivery, quantity and quality) have had their toll on the development of the livestock feed industry. The availability of good quality animal feeds at affordable prices can only be improved by creating an enabling environment for private sector investment. A national feeds policy to guide the industry was drafted in 2000 but has yet to be approved by the Parliament. The objective of the animal feeds policy is to maximise the potential of Uganda's livestock resources on a sustainable basis within the context of sound environment management (MAAIF, 2000). The policy emphasises increased production, supply and availability of good quality feeds for all categories of livestock at the lowest cost. The following articles of the draft policy are particularly noteworthy:

- **Article 3** provides guidelines on importation, manufacture and sale of animal feeds and feed ingredients.
- **Article 4** calls upon all persons, firms, corporations etc. engaged in the production, selling or distribution of animal feeds to indicate on the package a written statement containing the following: name and address of manufacturer, brand name, net weight, description and percent of each ingredient in the feed, the species and the type of animal for which the feed is intended, date of manufacture and expiry and the recommended conditions for handling, storage and use.
- **Article 5** specifies quality control services; this article puts in place mechanisms of maintaining and controlling animal feed quality.
- **Article 6** deals with adulterated feed/feedstuffs; in this article guidelines for storage and transportation of feed and feedstuff and the penalties, which include fines and maximum jail terms are stipulated.

Catfish hatchery operators are hardest hit by the absence of affordable manufactured commercial feeds and as mentioned above have resorted to importing starter diets. The FISH project also initially imported 16 tonnes of fish feed from a USA based feed company (ZEIGLER BROS., INC.), during December 2005. By using the imported feeds farmers have demonstrated the value of well balanced feeds and this may motivate local entrepreneurs to invest in an appropriate aqua-feedmill. According to a private commercial fish farm (Sunfish Farms Ltd.), which imported feeds from South Africa in November 2005, feeds are charged with a holding tax of 6 percent, value added tax at 18 percent and import duty of 10 percent. There is no information with regard to taxes on locally manufactured feeds. Farmers have made a request to government to waiver the import duty on aquafeeds, while the governments' stand, on the other hand, is to waiver taxes and duty on feed manufacturing machinery so as to encourage local manufacturing. Clearly there is a need for more dialogue to resolve these issues such that a win-win situation is created.

4. PROBLEMS AND CONSTRAINTS

- The lack of an affordable industrially manufactured pelleted feed remains one of the major constraints to the development of aquaculture in Uganda. The manufactures are unsure of a sufficient and sustained demand to warrant the high investment costs. On the other hand, many fish farmers claim that they cannot expand their business without high quality manufactured feeds.
- Farmers are unaware of the opportunities offered by farm-made feeds.
- There are many locally available ingredients that can be incorporated in fish feeds.

However, supply and price fluctuations can be crippling. Hence there is a need for farmers to invest in storage facilities, which will allow them to purchase adequate quantities of ingredients when prices are favourable.

- Poor processing, handling and storage affects the quality (mould, high sand content, mixed ingredients) of many raw material, such as fishmeal, rice bran and others. This in turn affects the quality of farm-made feeds.
- Accessibility to feed ingredients is constrained by poor infrastructure (roads, storage facilities) in remote parts of the country where feed crops are produced as well as by the high transport and fuel costs (US$1.00 and 1.22 per litre of petrol and diesel, respectively).
- Most fish farmers are poor and cannot afford to buy and store feed ingredients for sustainable on-farm feed processing and hence only purchase small quantities at high retail prices for immediate use. This reduces their profit margins and in some instances aquaculture becomes uneconomical. It is very difficult to make reasonable suggestions on how such farmers might escape the poverty trap, except that the state should provide adequate infrastructure and invest more heavily in education and health services in rural areas.
- Preparation of farm-made feeds is constrained by a lack of electricity and machinery on most fish farms in the country. Some fish farmers use hand operated mincers to make feeds, but this restricts the size of the fish farming operation. Unfortunately only a handful of farms are on the national power grid and farmers that use generators are constrained by the high fuel cost.
- The method of broadcasting milled feeds on the water surface is wasteful. This calls for improved skills and knowledge transfer.
- There is a paucity of data on the current use of feed ingredients as most farmers do not keep records. It is therefore difficult to determine the total cost of inputs (including feeds) and outputs, hence important indices such the feed conversion ratios cannot be determined.
- Inorganic fertilizers are readily available in Uganda. However, the high unit cost is a major constraint. Organic fertilizer (manure) is available all year round though farmers often cannot source, purchase and or store adequate quantities.

5. RESOURCE AVAILABILITY AND EXPANSION OF AQUACULTURE

Uganda is endowed with a wide variety of aquatic and agricultural resources that can support rapid growth of the aquaculture sector. Nearly 18 percent of Uganda's total surface area is covered by rivers and lakes and wetlands and rainfall ranges between 600–2 500 mm per annum. The water and soil resources offer great opportunity for land and water based aquaculture. This, coupled with the widening gap between fish demand and supply in Uganda, and in the region as a whole, and the over fished (and or destroyed) natural fish stocks provides the impetus for investment in and expansion of aquaculture.

Successful aquaculture industries are often and usually preceded by a successful fishing industry, which establishes fishery products, markets and infrastructure for processing and distribution. The established markets for Nile perch and other indigenous fish species coupled with the established processing, transport and other infrastructure, entrepreneurial interest and supportive economic policy will synergistically work to promote aquaculture development in Uganda.

6. RECOMMENDATIONS FOR THE IMPROVED UTILIZATION OF FERTILIZER AND FEED RESOURCES

1. Suitable feed ingredients from different agro-ecological zones must be identified and analysed and an aquafeeds database must be developed for each agro-ecological zone.

2. The soils of the various agro-ecological zones must be analyzed to determine nutrients that are likely to be limiting and these data must be used to develop a country profile for aquaculture development and investment.
3. Farmers must be trained in the use of fertilizers, handling, application and monitoring of fish production.
4. Fish farmers must be trained to keep records to estimate production and profitability. There is a need for a comprehensive programme to generate vital statistics to serve as benchmarks for aquaculture investment in the industry. Currently it is not clear what it takes to produce a kilogramme of tilapia or any fish species cultured in Uganda.
5. An inventory of fish farmers in the country must be established and maintained to estimate their potential, full production capacity and feed requirements.
6. Guidelines for farm-made feed formulation, processing, handling, storage and application and optimal fertilizer use must be developed.
7. The production and processing of soybeans must be promoted as an alternative to fishmeal. This is of particular importance because of the demand for *R. argentea* as food.
8. There is a need to revive and modernise traditional granaries for effective feed storage.

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APPENDIX
APPENDIX A: Feed formulation for North African catfish

A.1. Recommended formulation of a dry feed for *Clarias gariepinus* larvae and early juveniles, procedure to manufacture feed and its application

Ingredients	Composition (% as fed basis)
Torula yeast (*Candida utilis*)	50
Fishmeal	43
Vitamin and mineral premix	1
Fish oil	3
Sunflower oil	3
Total	100

Procedure:

1. Mix yeast and fishmeal with water to produce dough.
2. Roll dough out into thin cakes and dry at 45°C in oven.
3. Grind the dry cakes and sieve into particles of size ranges 125–200 µm and 200–350 µm.
4. On a daily basis, mix the proportional amount of oil and vitamins with an appropriate amount of stock mixture.
5. Discard what is not used within 24 hours.

Application:

Use fine particles (125–200 µm) for the first four days and large particles (200–350 µm) on subsequent days. Apply at least 20 g per 500 litre container every 2 hours, day and night, and in any case, not less than 40% of body weight per day.

Source: www.ru.ac.za/academic/departments/difs (and see CD ROM Resources)

APPENDIX B: Agricultural calendar

B.1. Agricultural calendar for selected crops with potential for inclusion into fish feeds

Crops	Month	Zone/regions			
		Northern	Eastern	Western	Central
Cotton	May-June	Planting	Planting	-	-
	June-July	-	-	Planting	Planting
	October	Harvesting	Harvesting	-	-
Maize	November	-	-	Harvesting	Harvesting
	February		Planting starts	Planting starts	Planting starts
	March	Planting starts	Planting continues	Planting continues	Planting continues
	April	Planting continues	Planting continues	Planting continues	Planting continues
	May	-	-	Planting continues	-
	June	Harvesting green maize	Harvesting green maize	Harvesting green maize	Harvesting green maize
	July-August	Harvest, dry	Harvesting in high altitude areas starts	Continue harvesting	Complete harvesting & plants for second rains in August
	September	Plant in wetter areas ends mid month	Harvesting & planting in highlands & ends same month.	Complete harvesting & plants for second rains & ends same month.	End of planting
	October	Start harvesting	-	-	-
	November	Harvesting	Harvesting	Harvesting	Start harvesting
	December	End of harvesting	End of harvesting	End of harvesting	End of harvesting
Cassava/sweet potatoes (leaves)	February	Start planting in wetter areas	Details of the crop calendar are same as in the northern region.	-	Details of the crop calendar are same as in the northern region.
	March-May	Planting continues & ends in May		Planting starts in March & ends in April	
	May–July	Harvesting starts in May & harvesting is completed in July		Partial harvesting start in June and harvesting is completed in July	
	August–October	Plating 2nd rains start & ends in October		Plating 2nd rains start & ends in October	
	December–February	Starts harvesting & ends in February following year	-	Starts harvesting & ends in February following year	-

B.1. Continued

Crops	Month	Zone/regions			
		Northern	**Eastern**	**Western**	**Central**
Beans/ soybeans	January- May	Planting start mid March or end month & ends in April	Planting start in February & end in March. Green harvest start in April	Planting start mid March in dry areas & end in May.	Early planting start January & ends in March, Green harvest in April
	June-August	Green harvest start in June	Harvesting continues & harvest completed in July.	Green harvest starts in June & completed in August.	Harvesting continues & harvest completed in July.
	August–October	Harvesting continue & harvest completed in October	Planting for 2nd rains & ends in mid September	Planting for 2nd rains & in October in drier areas	Planting for 2nd rains in September
	November–December	No activities	Start green harvesting & complete harvesting in December	Start green harvesting	Start green harvesting in November & complete harvesting in December.
	January following year	No activities	-	Complete harvesting	-
Vegetables (leaves)	January-March	Harvest & bed preparation, Sow nursery beds & begin transplant in March	Sow nursery beds & harvest in valley swamps, transplanting starts & main transplanting in March	Maintain nursery swamp crops, sow nursery, prepare field in February & transplant in March	Maintain nursery swamp crops, sow nursery, prepare field in February & transplant in February & continue sowing and transplanting in March
	April-May	Transplant, maintain old gardens, harvest up to June.	Transplant continued, hardening of seedling for may transplant, start regular harvesting in May, complete 1st rains planting except near valleys & continues regular harvesting.	Transplant up to June, Harvest earlier crops, sow nursery beds & plant swamp crops	Continue sow, transplant up to may, harvesting continue up to June
	June-September	Maintain fields & nursery beds, harvest, sow nursery beds	End of 1st rains planting in June except in valleys/ swamps, harvesting, sow new nurseries in July & start transplanting in August.	Sow nursery beds & plant swamp crops in June, harvest and prepare fields in July, maintain swamp crops, prepare new fields for nurseries, maintain old fields & harvest. Harden seedlings in September for October planting	Continue harvesting in June, maintain swamp crops, prepare new fields for nurseries, sow nurseries up to August & transplant in September
	October-December	Prepare valley swamps fringes, harvest old fields, plant out in swamps in December	Continues planting & sow nursery beds for valley and swamp fringes harvest up to December, land preparation and sowing beds in December.	Continue planting (valley/ swamps), Start harvest in November and Open nursery beds in December.	Continue planting, start harvesting in October up to December, Preparation of new fields and nurseries in December.