A review of on-farm feed management practices for North African catfish (*Clarias gariepinus*) in sub-Saharan Africa

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ABSTRACT

This review considers feed management practices for North African catfish (*Clarias gariepinus*) in sub-Saharan Africa. Clariid catfish production in the subcontinent is increasing exponentially, particularly in Uganda. Semi-intensive pond culture is still the most prevalent production system, while intensive tank culture is becoming more popular in peri-urban areas in Nigeria. Total production in these two countries now exceeds 178 000 tonnes annually. Catfish are now commonly spawned and their larvae reared in hatcheries for ten to 14 days, after which they are reared in nursery ponds or in tanks. Extensive rearing of larvae, after yolk sac absorption, in ponds is now less often practiced than in the past. Where it is still practiced, successful larval rearing and satisfactory survival rates depend mainly on adequate fertilization schedules. Feed management practices in hatcheries are closely matched with the physiological and endocrinological ontogeny of the fish. For optimal survival and growth, live food (mainly Artemia) is required for the first five days after the start of exogenous feeding, after which the fish can be weaned onto a dry starter feed. Up to a size of 5 g, the species has a high protein demand (>50 percent). Extensive farming of catfish in ponds is largely a subsistence activity and is practiced mainly in polyculture with tilapia that serve as fodder fish, and using a single ingredient feed such as maize or wheat bran. Semi-intensive on-growing of catfish in static and flow-through ponds, as well as under high-density tank culture conditions requires a complete feed; production levels achieved in these three systems are 15–24 tonnes/ha/cycle, 40 tonnes/ha/cycle and 385 kg/m^3/cycle, respectively. Results show that floating extruded pellets with a protein content of 30–35 percent are preferred by farmers. The duration of the grow-out cycle depends on the size of fish required by the market. At temperatures between 26 and 28 °C the fish can be grown from 1 g to 800 g in seven months. Feed conversion ratios (FCR) are

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size dependent, and best ratios are obtained by feeding the fish to satiation while observing their feeding response. Daily ration tables serve largely as a guideline. In ponds, the fish are fed two to three times per day, while under high-density tank conditions they are fed five to six times per day. During the early juvenile phases (1–24 g), FCR are commonly <1:1; from 25 g to 800 g FCR of 1.2:1 are achievable. There have been significant advances in feed availability and quality in the region, particularly in Uganda, although it would appear that weaning diets and starter crumbles are still being imported.

1. INTRODUCTION

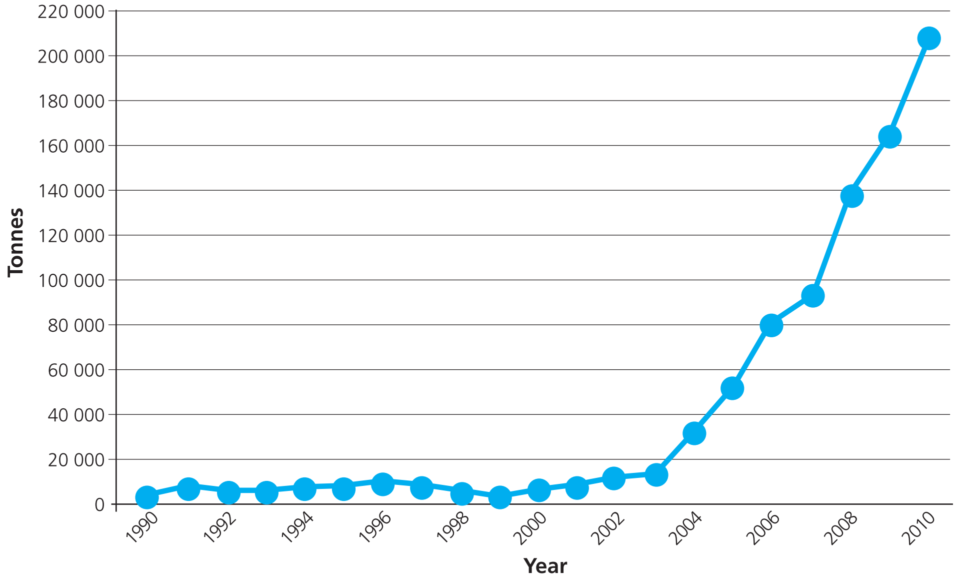
While the aquaculture attributes of the North African or sharptooth catfish, *Clarias gariepinus* have been recognized since the 1940s (Hey, 1941), the basic technologies and protocols for the farming of the species were developed much later, mainly from the 1960s to the late 1990s (e.g. Micha, 1971, 1972; El Bolock, 1973; De Kimpe and Micha, 1974; Richter, 1976; Hogendoorn, 1979, 1981; Bok and Jongbloed, 1984; Viveen *et al.*, 1985; Verreth and Den Bieman, 1987; Hecht, Uys and Britz, 1988; De Graaf and Janssen, 1996,). These studies provided the basic information upon which the future research and farming of North African catfish would be founded. Many mistakes were made along the road to commercialization (Hecht, Oellermann and Verheust, 1996), and it is only in the more recent past (i.e. in the first decade of the new millennium) that *C. gariepinus* farm production figures for sub-Saharan Africa (Table 1) have become significant (Figure 1), particularly in Nigeria and latterly in Uganda (Figure 2). The growth of the catfish farming industry in Nigeria was market driven, while the spike in production in Uganda in 2006 is generally regarded as a combination of market forces and a well-directed donor project initiative (Isyagi *et al.*, 2009a). According to FAO (2012), North African catfish was the most important commercial aquaculture species in 2010 in sub-Saharan Africa (198 296 tonnes), followed by Nile tilapia (*Oreochromis niloticus*) (60 350 tonnes). The farming of *C. gariepinus* in Europe is a minor activity (FAO, 2012) and is currently occurring only in the Netherlands, Hungary and Poland (1 810, 3 200 and 650 tonnes, respectively, in 2010). In Asia, *C. gariepinus* is hybridized with *C. batrachus* and *C. macrocephalus*. Clariids are an important component of the total farmed fish production in the Asia Region, which in 2010 contributed a production of 453 209 tonnes (FAO, 2012).

TABLE 1
Total production (tonnes) of clariid catfish in Africa, 2004 to 2010

	2004	2005	2006	2007	2008	2009	2010
Egypt	459	10 180	6 058	5 287	13 944	17 895	9 717
Kenya	320	318	302	890	935	1 047	2 188
Nigeria	26 750	34 582	51 916	52 229	86 130	89 193	130 318
Uganda	3 827	6 528	20 941	34 096	35 000	54 956	63 000
Other (n=22)	721	617	922	1 037	1 159	1 669	2 790
Sub-Saharan subtotal	31 618	42 045	74 081	88 252	123 224	146 865	198 296
Total	**32 077**	**52 225**	**80 139**	**93 539**	**137 168**	**164 760**	**208 013**

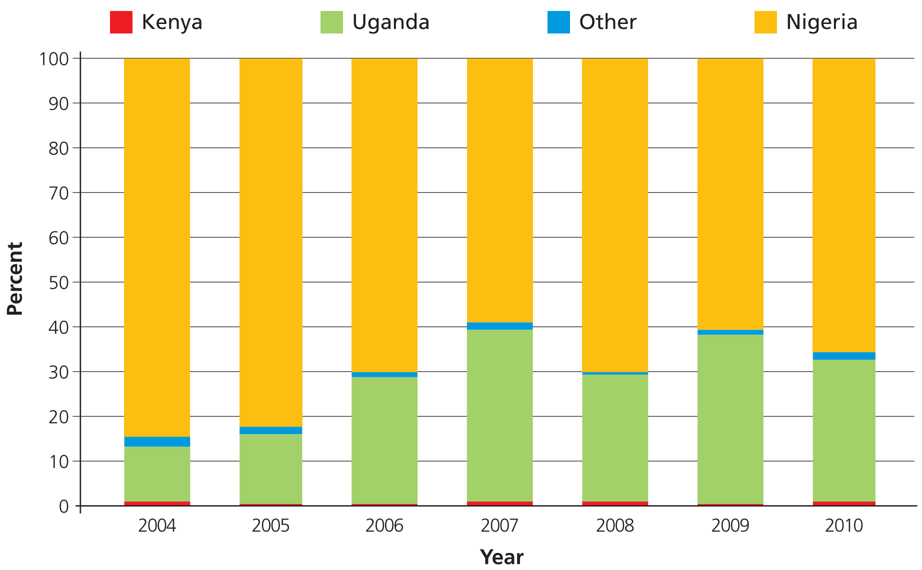
Source: FAO (2012).

FIGURE 1
Clariid catfish production in Africa, 1990 to 2010



Source: FAO (2012).

FIGURE 2
Percent contribution by major[1] sub-Saharan clariid catfish producer countries[2]



[1] Defined as having a production of >1 500 tonnes in 2010.
[2] The 'other' category consists of 22 sub-Saharan countries in which clariid catfish are also produced in lesser quantities.

Source: FAO (2012).

The significant increases in annual production in sub-Saharan Africa from around 2000 onwards can be partially ascribed to the concerted research efforts on the nutritional requirements of the species during all life history stages, feed formulation, optimization of feeding and feed management practices and the development of high-density tank farming practices. However, more importantly, there has been a switch in the profile of catfish farmers from small-scale rural farmers to educated, mainly urban-based, young entrepreneurs who have easier access to capital and for whom access to information is less difficult. In sub-Saharan Africa, clariid catfish are farmed in one of three basic ways *viz*. extensive polyculture in ponds, semi-intensive pond culture and intensive tank culture.

In smallholder ponds, the fish either contribute to some extent towards improved nutrition at the household level or (when produced in surplus), are (rarely) sold for cash. The fish are normally produced in polyculture with tilapiine species that serve as fodder fish. The most common feed used under this scenario is maize or wheat bran (from which the catfish also benefit marginally), and some (normally inadequate) quantity of manure, compost and possibly some fertilizer are applied. Under this scenario, production rarely exceeds 1.5 tonnes/ha/year, which equates to ~30 kg of fish per 200 m^2 pond per annum.

Commercial-scale production of catfish in ponds takes place in various ways. Under monoculture, static pond or flow-through conditions, the fish are normally fed on a complete, pelleted feed or on farm-made feeds. Production levels under static pond conditions range from 15–20 tonnes/ha/cycle. Under flow-through conditions, production ranges between 25 and 40 tonnes/ha/cycle. In polyculture conditions in stagnant ponds, catfish are often grown together with *O. niloticus* and fed on farm-made feeds, with total yields ranging from 5 to 8 tonnes/ha/year (Ayinla, 2007). During the period 1985 to 1998, there was a concerted research effort on high-density tank farming of *Clarias gariepinus* under recirculating conditions (Oellermann and Hecht, 1996; Eding and Kamstra, 2002; Eding *et al.*, 2006). This technology was first put into practice in the Netherlands and is now commonly used in Nigeria, Hungary and Poland. It should, however, be noted that the bulk of catfish in Nigeria and Uganda is still produced in ponds (Akinwole and Faturoti, 2007; J. Rutaisire, Department of Fisheries, Uganda, personal communication 2010). High-density tank farms in Nigeria, and now also in Uganda, are situated mainly in peri-urban environments and in other areas where there is ready access to supplies and services (Akinwole and Faturoti, 2007).

In Uganda and Kenya, *C. gariepinus* is not only farmed commercially as a food fish, but fingerlings are also produced as live baitfish for the Nile perch (*Lates niloticus*) fishery in Lake Victoria. Currently the demand for 8–10 g fingerlings as live bait is around 700 million per year in the Lake Victoria basin area, while the demand in Uganda alone is around 300 million per year (Isyagi *et al.*, 2009a, b).

This paper reviews current and best on-farm feeding and feed management practices during the various life history stages. Based on current practices, several recommendations are provided within the text that may help to improve production and feed conversion ratios (FCR) and lead to reduced levels of waste.

2. FEEDING OF LARVAE AND EARLY JUVENILES

Catfish larvae are generally reared to fingerlings in one of three ways;

- Under commercial farming conditions, they are either intensively reared to fingerling size solely in a hatchery, after which they are on-grown under pond or high-density tank culture conditions.
- Alternatively, they are reared in a hatchery for a period of up to 14 days and then grown to fingerling size for a further 30 + days in nursery ponds, after which they are stocked into larger on-growing ponds.
- Extensive larval rearing encompasses the stocking of 3-day-old larvae into well prepared and protected nursery ponds, where they are on-grown to fingerling size before being stocked into larger grow-out ponds.

The feed to be used and the applied feeding strategy are largely dependent on whether the larvae are reared extensively or intensively.

2.1 Extensive rearing

Under extensive rearing conditions, the ponds are prepared such that there is an abundance of zooplankton. This takes place up to 14 days prior to stocking and consists of liming and fertilization. ASEAN (1978) and Viveen *et al.* (1985) recommend the use of 100–150 kg/ha of quicklime, which is added to the damp pond bottom to eliminate pathogens and invertebrate predators. The pond is then left for 7–14 days, after which it is filled with water to a depth of 30 cm and the pH of the water adjusted by adding agricultural lime. Ensuring a good zooplankton bloom requires adequate fertilization with chemical or organic fertilizers. The choice of either is largely determined by availability and the economic circumstances of the farmer. The main inorganic fertilizers used are super-phosphate (approximately 20 percent P_2O_5), triple super-phosphate (45 percent P_2O_5), urea (about 45 percent N) and NPK 15:15:15 (15 percent N, 15 percent P_2O_5 and 15 percent K_2O). It is strongly recommended to dissolve the fertilizers and then to spread the solution evenly over the water surface (ASEAN, 1978). In the absence of any specific work on North African catfish fry or fingerling rearing ponds, it is advisable to follow the findings and recommendation made by Hepher (1963, 1967) and Boyd (1982). The work by Hepher (1963, 1967) has shown that applying fertilizer doses greater than 0.5 mg P/L or 1.4 mg N/L has no biological or economic justification. These levels are equivalent to application rates of 60 kg/ha of single super-phosphate (11 kg P_2O_5/ha) and 60 kg/ha ammonium sulphate (13 kg N/ha) respectively, applied at two-weekly intervals (0.8–1.0 m water depth, 8 000–10 000 m^3 water/ha) (Tacon, 1987, 1988). Similarly, Boyd (1982) recommends chemical fertilization strategies to maintain soluble nitrogen and orthophosphate at 0.95 mg N/L and 0.1–0.5 mg P/L, respectively.

The most commonly used organic fertilizers are chicken, pig and cow manure. Table 2 shows several application schedules. It is important to note that the application rates are not absolute and only serve as guidelines. If an adequate phytoplankton bloom is not achieved within six to eight sunny days, then more manure should be added. Plankton levels are adequate when the water has a green colour and a Secchi disk reading of around 20–25 cm. The biological effect of organic fertilization is improved if the manure is spread evenly over the water surface in a liquid or semi-liquid form (Tacon, 1988). Fish ponds can only assimilate a certain amount of manure per day. Hence to prevent de-oxygenation in manure-loaded ponds (due to unchecked peaks in bacterial growth and phytoplankton blooms), manure should be added frequently (daily, if possible) and in small amounts, and during mid-morning when oxygen levels are rising (Hepher and Pruginin, 1981).

Table 3 shows a mixed (inorganic and organic) fertilization schedule that can also be used to develop good zooplankton blooms.

TABLE 2
Fertilization rates using animal manure

Fertilizer	Rates (kg dry weight/100 m^2)
Poultry manure	25 kg initially and then 3–5 kg every 10 days
Pig manure	7 kg every 2nd day
Cow dung	10 kg every 2nd day

Source: Tacon (1988).

TABLE 3

Combined fertilization rates

Manure/fertilizer	Rate (kg/week/100 m^2)
Dry poultry manure	10–20
Urea	0.4–0.8
Triple superphosphate	0.1–0.2

Source: Janssen (1985).

Periphyton can also be used successfully for the rearing of *Clarias* larvae (Nwachukwa, 1999). Amisah, Adjei-Boateng and Afianu (2008) have demonstrated the beneficial combined effect of pond fertilization and the use of bamboo poles for the development of periphyton. In their study, bamboo pole density was 4 per m^2 and ponds were fertilized with pig manure at an initial rate of 20 kg/100 m^2 and then every second week at 10 kg/100 m^2.

Clarias larvae start exogenous feeding approximately 80 hours after hatching (depending on temperature) and are therefore normally transferred into well prepared and protected nursery ponds when they are three days old. Nursery ponds vary in size between 100 and 250 m^2; in sub-Saharan Africa nursery ponds must be protected against the African clawed toad, *Xenopus laevis*, by way of a smooth wall made of plastic, roof sheeting or other suitable material. If this precaution is not taken, then the majority, if not all, of the fry will be lost to predation. The ponds are stocked at a density of 100–250 larvae/m^2. From the day of stocking, the fish must receive supplementary feed. At a density of 100 fry/m^2 the recommended feeding levels are 1 kg rice or wheat bran, plus 1 kg/100 m^2 of crumbled, formulated feed containing some fishmeal for the first three weeks. For the following two weeks, the bran ration remains the same but the formulated feed ration increases to 2 kg/100 m^2/day, fed in two equal meals. After three weeks, it is advisable to grade the fish into two or three size groups to reduce cannibalism. With good feeding and management practices, survival rates of 40 percent and a final fish weight of 3 g can be achieved during 50-day rearing cycles (De Graaf and Janssen, 1996). These authors are also of the opinion that the most critical factor (on condition that the pond is protected) is most probably the availability of zooplankton during the first few days of the rearing cycle.

2.2 Intensive rearing

The larval rearing protocol under intensive hatchery rearing conditions is completely different and is very closely allied to the ontogeny of the alimentary and endocrine systems. It normally lasts for a period of 12 to 14 days and ideally takes place at the optimum temperature for growth (28 °C).

Research has shown that live food in the form of enriched *Artemia* nauplii, small *Daphnia*, *Moina* or other zooplankton of suitable size is essential for the first four to six days after the start of exogenous feeding (Hogendoorn, 1980; Uys and Hecht, 1985; Verreth and van Tongeren, 1989; Haylor, 1993; Hecht, 1996; Awaiss and Kestemont, 1998) and is preferable to dry food only (Appelbaum and van Damme, 1988). The reason for this is that the stomach of the larvae is not functional at the start of exogenous feeding (three days after hatching), and its development extends beyond the eleuthero-embryo stage into the larval stage (Stroband and Kroon, 1981). The stomach only becomes functional four to five days after the start of exogenous feeding (Verreth *et al.*, 1992; Segner *et al.*, 1993). Once the stomach becomes functional and pepsin activity contributes significantly to protein digestion, the larvae can be weaned from live food to a dry feed (Verreth and van Tongeren, 1989; Verreth *et al.*, 1993).

Larvae and early juveniles of *C. gariepinus* (up to approximately 5 g) have a high protein demand of around 50–55 percent and a lipid requirement of 9 percent (Uys and Hecht, 1985), of which at least 10 percent should consist of fish oil (Uys, 1989; Kerdchuen, 1992). The carbohydrate content can be as high as 21 percent of the diet (Uys and Hecht, 1985). For optimal growth, the composition of any dry feed that will be fed from 5 or 6 days after hatching (dah) until at least 14 dah must meet the nutrient requirements as outlined above.

Several larval and early juvenile rearing protocols have been developed. The four most commonly used protocols are shown in Table 4; all result in good growth and survival rates. Optimum pellet crumble size during this period is 2.2 percent of the mean total length of the larvae, and early juveniles should be fed at 25 percent of body weight per day at two-hour intervals (Uys, 1984). Predicted feeding rates are also provided by Verreth and Den Bieman (1987). Production costs can be significantly reduced by using small-strain *Daphnia* instead of *Artemia*.

TABLE 4

Four feeding protocols for North African catfish, *Clarias gariepinus*[1]

Protocol 1 (dah)[2,3]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**15/16–30/32**
Artemia			—	—	—	—	—	→								
Weaning diet			—	—	—	—	—	—	—	—	—	—	—	—	→	
Grow-out feed															—	→
Protocol 2 (dah)[4]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**15/16–30/32**
Artemia			—	—	—	—	—	—	→							
Weaning diet												—	—	—	—	→
Grow-out feed															—	→
Protocol 3 (dah)[5]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**15/16–30/32**
Artemia			—	—	—	—	—	—	→							
Weaning diet								—	—	—	—	→				
Grow-out feed												—	—	—	—	→
Protocol 4 (dah)[6]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**15/16–30/32**
Artemia			—	—	—	—	—	—	—	—	—	—	—	→		
Weaning diet/bran															—	→

[1] Larvae start exogenous feeding ca. 80 hours after hatching

[2] Protocol 1 (Hecht, Uys and Britz, 1988): *Artemia* is presented to the fish once a day

[3] dah = days after hatching

[4] Protocol 2 (Verreth, Storch and Segner, 1987): *Artemia* restricted up to four times per day

[5] Protocol 3 (Oellerman, 1995): *Artemia* restricted up to four times per day

[6] Protocol 4 (Janssen, 1985; De Graaf and Janssen, 1996): *Artemia* presented ad libitum

After 12–14 days, the fry are stocked into nursery ponds at densities ranging from 65 to 2 000/m^2 (Viveen *et al.*, 1985; Hecht, Uys and Britz, 1988; Isyagi *et al.*, 2009b). The density at which fry are stocked depends on fish age and the intensity of rearing protocols. Under pond-farming conditions, it is recommended to feed the fry three times per day at 25 percent of body weight per day, using a 38–40 percent protein diet (Hecht, Uys and Britz, 1988). If the larvae and early juveniles are reared in tanks, then the feed should have a protein content of around 50 percent. When the fish attain an average weight of 1–2 g, they are ready to be stocked into ponds or tanks for on-growing.

Cannibalism is a serious problem during larval and early juvenile rearing, particularly under hatchery conditions (Hecht and Appelbaum, 1988). The rate of cannibalism is affected *inter alia* by feeding frequency, food availability, light intensity and photoperiod (Hecht and Pienaar, 1993). Almazán, Schrama and Verreth (2004) showed that a reduction in swimming activity results in a lower incidence of aggressive behaviour. Hence feeding frequency, food availability and light intensity must be manipulated such that swimming activity is reduced to a minimum. This is achieved at low light intensity (<15 lux), continuous food availability and feeding the fish every two hours around the clock.

3. FEEDING DURING ON-GROWING

The species is produced in widely different farming systems ranging from highly intensive tank culture under flow-through or recirculating conditions to intensive, semi-intensive and extensive (small and large-scale, polyculture or monoculture) static or flow-through pond-culture systems. It is therefore not surprising that a wide range of feeds are used in the farming of this species. These include dry feeds ranging from single ingredient dry feeds, such as maize bran, to farm-made mixed feeds to formulated, floating or slow-sinking, extruded pellets, as well as single ingredient or mixed moist, farm-made feeds (Hecht, 2013).

The optimum pond size for catfish production was found to be 0.1 ha. This allows for optimum control of feed use and management of the production and harvesting cycle (Hecht, Uys and Britz, 1988). Under pond-farming conditions using formulated feeds, it is best to train the fish to feed in the same area of the pond at the same time of day. This is easily achieved and has several advantages. It allows the farmer to take good samples with which to assess average fish weight and fish health and ultimately facilitates harvesting. It is further recommended to feed the fish based on their feeding response. This allows the fish to be fed to satiation on a daily basis under variable environmental conditions (e.g. temperature, dissolved oxygen, pH, nitrogenous metabolites, barometric pressure), all of which affect daily feed intake. Feeding charts should serve as a guide to estimate daily rations (Table 5). During the on-growing cycle in ponds, fish are normally fed twice a day. It is an essential management practice to maintain good records of the daily amounts fed and the feeding response of the fish (Hecht, Uys and Britz, 1988; Isyagi *et al.*, 2009b).

TABLE 5

Recommended daily ration for North African catfish (expressed as % body weight/day)

Temperature (°C)	Fish size (g)					
	1–10	10–25	25–50	50–100	100–300	300–800
16	1.0	0.6	0.4	0.3	0.2	0.2
18	3.0	1.6	1.0	0.8	0.6	0.5
20	5.0	3.0	2.0	1.5	1.2	1.0
22	6.8	4.5	3.0	2.4	2.0	1.7
24	8.1	6.0	4.0	3.0	2.5	2.2
26	9.5	6.6	5.1	3.6	3.2	2.8
28	10.0	7.0	5.5	4.0	3.5	3.1
30	9.8	6.8	5.3	3.7	3.2	2.9
32	9.5	6.5	5.0	3.5	3.0	2.8

Source: Hogendoorn *et al.* (1983); Hecht, Uys and Britz (1988).

Under pond-farming conditions, it is advisable to feed the fish at the same time and at the same place each day such that they become accustomed to a particular feeding regime. This allows the farmer to feed on a response basis, which results in less waste and improved FCR (Isyagi *et al.*, 2009b). Under good pond management practices, FCR during grow-out of 1:1 are not uncommon, although this of course depends on the nutrient profile of the feed and the aptitude of the farmer.

3.1 Nutrient requirements and feed production and availability

The nutrient requirements of *Clarias gariepinus* are outlined in Table 6; based on this information various least-cost feeds of variable quality are available on the market throughout the region. In the two largest producer countries (Nigeria and Uganda), catfish feeds are readily available. In Nigeria, there are at least 12 commercial aquafeed producers, and products range from slow-sinking pellets to floating extruded pellets. In Uganda, there is one large producer (Ugachick) that produces a slow-sinking as well as an extruded floating catfish feed (30 percent protein pellets) and, as in Nigeria, there are many small-scale feed producers. All of the commercial feed producers in Nigeria essentially target the needs of catfish farmers. However, specifically formulated and extruded pellets (45 percent protein) for the early rearing stages of *C. gariepinus* are imported from South Africa and elsewhere (Ayinla, 2007).

TABLE 6
Dietary nutrient requirements of North African catfish (10–1 000 g)

Nutrient	Quantity[1]	References[2]
Crude protein (% min)	40–43	1, 2, 3, 4, 5, 6, 7, 8, 9
Least cost/appetite feeding protein requirement	35–38	1, 6
Crude lipid (% min)	10–12	1, 2, 6, 7
Carbohydrate (% recommended)	15–35	1, 6, 7, 10, 11, 12
Digestible energy (min, kJ/g)	14–16	1, 2, 13
Metabolizable energy (min, kJ/g	13	2
Gross energy (min, kJ/g)	22–24	2, 4, 7, 10
Protein to energy ratio (mg/kJ)	22–30	1, 2, 4, 7, 10
Lipid to carbohydrate ratio (g/g)	2.47	6

[1]Units stated in parentheses in column 1
[2]*Source*: 1: Uys (1989); 2: Machiels and Henken (1985); 3: Machiels and Henken (1987); 4: Degani, Ben-Zvi and Levanon (1989); 5: Fagbenro, Nwanna and Adebayo (1999); 6: Ali (2001); 7: Pantazis (1999); 8: Ali and Jauncey (2005b); 9: Ali and Jauncey (2005c); 10: Ali and Jauncey (2005a); 11: Balogun and Ologhobo (1989); 12: Heinsbroek, Van Thoor and Elizondo (1990); 13: Yilmaz *et al.* (2006).

Specifically formulated commercial catfish feeds are only available in certain African countries (i.e. Cameroon, Kenya, Nigeria, South Africa and Uganda) (Hecht, 2007). Extruded floating or slow-sinking pellets are currently only available in Nigeria, South Africa and Uganda. Large-scale, intensive catfish farmers throughout the African subcontinent are currently (2010) still not entirely satisfied with feed quality. It was not possible to obtain a list of ingredients that are used for the feeds except from Ugachick, which uses soy bean, maize, sunflower and wheat products, mukene (silver cyprinid, *Rastrineobola argentea*) fishmeal, unspecified fish oil, vegetable oil and bone meal from Nile perch skeletons. Ugachick in Uganda produces three different feeds for *Clarias*, the proximate composition of which is shown in Table 7. Because of the low protein content of the pre-starter and starter feeds, farmers in Nigeria and Uganda import these feeds from South Africa and elsewhere for the early rearing stages until the fish reach ~12 g (Ayinla, 2007; Rutaisire, 2007; Akinwole and Faturoti, 2007).

TABLE 7
Proximate composition of catfish feeds in Uganda and South Africa

	Crude protein (% min)	Crude lipid (% min - max)	Crude fibre (% max)	Ash (% max)	Ca (%)	P (%)
Ugachick (high protein, pre-starter)	39.9	8.5–9.5	5.5	7		
NutriScience (pre-starter)	45	8	4		3	7
Ugachick (starter)	35	8–10	7	7		
NutriScience (starter)	40	8	4		3	7
Ugachick Catfish (grower)	30	7–8.5	8	7		
NutriScience (grower)	35	7	4		3	7

Source: Information provided by feed manufacturers.

3.2 Feeding in intensive pond farming

Under both of the two intensive pond farming conditions described in sections 3.1 and 3.2 below, profitability depends largely on applying the correct feeding strategy. This implies that the feed satisfies the nutrient requirements of the fish at various sizes, feeding the right pellet size for easy consumption and low wastage, feeding the correct amounts and feeding at the right time(s) each day. When fish are fed correctly, growth rates are good and uniform across the population, FCR are low and pond water quality is optimized (Isyagi *et al*., 2009b).

3.2.1 Under flow-through conditions

Under intensive pond-farming conditions with water exchange, the fingerlings (~5 g) are stocked into grow-out ponds (0.1 ha) at a density of 100 000/ha and fed according to feeding response and the feeding schedule shown in Table 5. At the beginning of the production cycle and for about two months, the fish are fed three times per day, after which the frequency is reduced to twice a day. The fish population has to be thinned out at regular intervals to maintain a maximum biomass of not more than 40 tonnes/ha, at a water exchange rate of total pond volume once every four days. Under the prevailing thermal conditions, the fish can be harvested at 800 g after 10 months (Uys, 1989).

3.2.2 Without water exchange

The production capacity of ponds under static water management conditions is lower than under flow-through conditions. Under static conditions, using a complete sinking diet, the critical standing crop is around 15–20 tonnes/ha. The critical standing crop is defined as the biomass of fish in the pond when the growth rate begins to slow (Isyagi *et al.*, 2009b). While these yield levels are approximately 50 percent of those achieved under flow-through conditions, they are still extremely high. Isyagi *et al.* (2009b) suggest that fish <10 cm (~6 g) should not be used for on-growing. To obtain a lower mortality rate and a higher level of profitability, they recommend larger fingerlings of around 15 g. Based on a projected harvest weight of 800 g, 24 750 (15 g) fish are required per hectare. This allows for a 10 percent mortality rate during the grow-out period. Isyagi *et al.* (2009b) provide further detailed accounts of the feed choice, management of feed conversion ratios (FCR), record keeping and economic analyses of various feeding strategies under static pond-farming conditions in Uganda. Feed costs make up approximately 60–70 percent of variable costs. Moreover, they (*op cit.)* provide a suite of recommendations for on-farm feed management to ensure freshness and good fish health.

3.3 Feeding in small-scale farming

The farming of catfish by small-scale commercial farmers is becoming more popular in many sub-Saharan countries, including Mozambique, Zambia, Malawi, Kenya and Tanzania. Many of these farmers either cannot afford or do not have access to commercial formulated feeds and hence are forced to use farm-made feeds. For economic reasons, over 90 percent of the feeds used by fish farmers in sub-Saharan Africa are wet or dry feeds made on the farm or by small-scale feed producers (Hecht, 2007). Wet or moist ingredients that are commonly used for catfish feeds in Africa and Asia include chicken entrails, minced poultry farm mortalities, abattoir waste, butchery sweepings, fish market waste (mainly fish entrails), maggots, termites, earthworms, trash fish, hotel or restaurant kitchen waste and live juvenile tilapia. In most instances, these ingredients are mixed with milled oilseed cakes (soy, cotton, sunflower, palm kernel) and relatively inexpensive ingredients such as maize, wheat or rice bran and dried brewery waste.

Many farmers use wet ingredients such as chicken offal as a stand-alone feed and claim to achieve FCR of around 1.3:1 (Ayinla, 2007). Recent trials in Uganda have found that the use of chicken offal results in a high fat content of the meat and unacceptably high abdominal fat deposition (Matsiko and Mwanj, 2008). However, it should be noted that fish with low abdominal fat content are least preferred in many other regions in Africa. There is some evidence to suggest that juvenile catfish fed on mixed moist feeds (34 percent moisture) have poorer performance indices (i.e. weight gain, specific growth rate, FCR, protein efficiency ratio) than juveniles fed on a dry diet using the same ingredients (Fagbenro, 1994; Fagbenro and Jauncey,1994; Fagbenro, Jauncey and Krueger, 1997).

Several farm-made dry feeds are produced, and these range from formulated dry mixes fed to the fish in punctured bags, to moist feed cakes or balls and dry pellets. Preparation and manufacturing technologies are simple – raw materials are milled and cooked (or precooked, e.g. soybeans), mixed into a dough with water and extruded using a meat mincer. The ‘spaghetti-like’ product is sun-dried or dried in locally manufactured driers and cut or crumbled into appropriate sizes. Anti-oxidants are expensive and not commonly used by small-scale feed manufacturers, such that storage of farm-made feeds is problematic. This is compounded by the absence of proper feed drying facilities. Farmers are advised to mix and prepare only quantities that can be used within a few days. Depending on feeding practices, FCR of 1.1:1 have been reported for some farm-made feeds in Uganda and Kenya (Hecht, 2007).

Because of the high cost of vitamin and mineral premixes, farmers in Africa often use chicken layers mash, which contains minerals and vitamins, as one of the primary components of catfish feeds. In fact, pig and poultry feeds are also often used as alternate feeds for North African catfish throughout the African subcontinent (Liti, MacWere and Veverica, 2002; Nyandat, 2007). Alternative sources of minerals used in Nigeria include bone meal and crushed periwinkle shells (Ayinla, 2007). Gabriel *et al.* (2007) and Hecht (2013) provide succinct overviews of alternative ingredients that have been tested as ingredients for farm-made catfish feeds in sub-Saharan Africa.

3.4 Feeding in intensive tank culture conditions

The on-growing of African catfish under intensive tank culture conditions is somewhat different to pond culture (Oellerman, 1995; Oellermann and Hecht, 1996; Hecht, Oellermann and Verheust, 1996; Akinwole and Faturoti, 2007; Ayinla, 2007). Early fingerling, juvenile and grow-out production schedules are now fairly standardized and are briefly summarized as follows. Post-hatchery fry are stocked at a density of ~25 000/m^3 and on-grown to 4–5 g in ~30 days. At that stage, they are graded into three size classes. The smallest fish are discarded. Fish with an average weight of 4–5 g are then restocked into the tanks at ~8 500/m^3 and reared to 11–12 g in ~30 days. Up to this stage, the volume of the rearing tanks is generally between 0.5 and 4 m^3, while the tanks used for on-growing in Nigeria and South Africa range in size from 2 to 20 m^3 and are most commonly made of bricks and mortar. The 11–12 g fish are then stocked at 150 to 400 fish/m^3 and reared to market size (420–>850 g). At average temperatures of between 26 and 28 °C, the 12 g fish are grown to 850 g (using 30 percent protein feeds) in approximately 154 days at FCR ranging from 1.1 to 1.6:1 (Oellerman and Hecht, 1996; Akinwole and Faturoti, 2007). Depending on management, production levels range between 107 and 385 kg/m^3/6 month cycle (Oellerman and Hecht, 1996; Akinwole and Faturoti 2007).

Based on information provided by Akinwole and Faturoti (2007), it would appear that high-density tank farming in Nigeria using recirculating systems is still experiencing some teething problems, and these seem to be related to maintenance of good water quality. Nevertheless, comparison of production parameters shows that Nigerian farm results are good and approach the experimental results in the Netherlands (cf. Akinwole and Faturoti, 2007; Eding and Kamstra, 2002 and Eding *et al.*, 2006).

Because of the high densities at which the fish are reared, it is preferable to feed the fish five to six times per day. Under high-density tank farming conditions, daily ration tables are at best only guidelines; because of the high cost of feed, farmers are advised to monitor food consumption and to adjust rations on a daily basis depending on the feeding intensity of the fish. A sample of fish is normally weighed on a weekly basis (or every 10 days) to check feed consumption against recommended levels.

Further strategies to reduce feed costs should be developed. For example, Ali (2001) found that alternating periods of restricted feeding (maintenance requirement) for three days and appetite feeding for the following four days is a plausible way in which to reduce feed input cost for this species. However, in a later study, Ali and Jauncey (2004) showed that *C. gariepinus* only shows partial compensatory growth under periods of restricted and satiation feeding.

Feeding of African catfish under intensive tank culture conditions can be done by hand or can be mechanized using demand feeders or compressed air feed distributors. Demand feeders under these conditions are not recommended, as the pendulum is in continuous motion, which may lead to feed losses. Despite the switch to intensive tank culture, very little is known about the way to manage and optimize feed use under these conditions, and there is a clear need to investigate this.

4. CONCLUSIONS

The farming of African catfish in sub-Saharan Africa is a commercial activity (defined as a national production of >1 500 tonnes per annum) in only three countries *viz*. Nigeria, Uganda and Kenya. In all other countries that report production statistics, the activity is best described as marginal. The reasons for this are varied. In South Africa, market resistance is the only impediment; while in many other countries access to information, high cost and availability of capital, inadequate supplies and services and poor infrastructure seem to be the overriding reasons. The technology for the farming of the species at various levels of intensity is, however, very well established. It appears that Uganda has recently become the centre of catfish farming development for food and for the live bait sector.

There have been significant improvements in the aquafeed sector since 2005 (Hecht, 2007), both in terms of quality and supply. Most countries in the region have adequate resources to manufacture appropriate feeds, although the availability and cost of fishmeal and soybean meal or oilseed cake are major constraints in most countries (Hecht, 2007). The general paucity of good-quality aquafeeds in the region is generally a factor of scale. Uganda provides the best example of this supposition. In 2005, commercial aquafeeds were not available in Uganda (Rutaisire, 2007) but now, because of the rapid increase in catfish production, all the necessary feeds (fry, fingerling and on-growing feeds) inclusive of floating extruded feeds are manufactured locally. It is however unknown what proportion of the Ugandan catfish production is reared on formulated and/or farm-made feeds. Although it is reported that farmers in Nigeria and Uganda use high-protein imported feeds during the nursery phase, it is anticipated that more appropriate feeds will also soon be manufactured in all major catfish-producer countries.

Commercial feeding schedules during the nursery and on-growing phases have also been fairly standardized. Live food (mainly *Artemia*) is generally used for the first five to six days of exogenous feeding, after which the juveniles are weaned onto dry feeds. During the early and late on-growing phases in ponds, the fish are fed by hand to satiation at the same place and time; this reduces wastage. Under high-density tank farming conditions, the fish are either fed by hand or through the use of demand feeders. The use of the latter is considered wasteful, and further research is required to optimize feeding practices in tanks under high-density conditions.

Subsistence farming of catfish under polyculture or monoculture conditions using single ingredient feeds will remain marginal and make insignificant contributions to food security and national production figures.

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