Tilapia feed management practices in sub-Saharan Africa

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El-Sayed, A.-F.M. 2013. Tilapia feed management practices in sub-Saharan Africa. *In* M.R. Hasan and M.B. New, eds. *On-farm feeding and feed management in aquaculture.* FAO Fisheries and Aquaculture Technical Paper No. 583. Rome, FAO. pp. 377–405.

ABSTRACT

Tilapia is a traditional source of nutrition for the general population in many countries in sub-Saharan Africa (SSA). However, farmed tilapia production in SSA is relatively low, representing only about 2.5 percent of global tilapia production in 2010. At the continental level, the Arab Republic of Egypt was the largest contributor to African tilapia culture (86.3 percent) in 2010, while SSA contributed only 13.7 percent. This review considers only those SSA countries whose tilapia production exceeds 500 tonnes per year: the Republic of Côte d'Ivoire, the Democratic Republic of Congo, the Republic of Ghana, the Republic of Kenya, the Republic of Malawi, the Federal Republic of Nigeria, the Republic of the Sudan, the Republic of Uganda, the Republic of Zambia and the Republic of Zimbabwe. Tilapia culture in SSA has recently been growing at an outstanding rate, increasing during the period 2006 to 2010 from 39 883 tonnes to 88 238 tonnes/year. Tilapia culture in SSA is mainly a small-scale, semi-intensive activity, practiced mainly by non-commercial farmers in freshwater earthen ponds. Medium and large-scale, intensive cage culture is also practiced in a few countries (e.g. Ghana, Malawi and Zimbabwe). Semi-intensive production relies on pond fertilization and enhanced natural food. Composts, chicken manure, cattle manure or pig manure are generally applied. Both urea and di-ammonium phosphate (DAP) are also used for pond fertilization. Ingredients suitable for tilapia feed manufacture are available in most of the region. However, aquafeed mills are few, and commercial feed production is limited because the demand for commercial fish feed is too low to justify industrial-scale production. Therefore, commercial tilapia feeds are only manufactured in a few SSA countries (Cameroon, Kenya, Malawi, Nigeria, Zambia and Uganda). The high transport costs and quality issues with locally manufactured diets force fish farmers to rely on imported pelleted feeds or farm-made feeds. Data on commercial feed costs are provided in this review. Farm-made tilapia feed is widely used in the whole region, particularly in Nigeria, Uganda and Zambia. Over 100 000 tonnes of farm-made feeds are currently produced annually, mostly fed to tilapia in the form of dry pellets, formulated mash or formulated wet dough. Feeding tilapia with only cereal bran (corn, rice and wheat) is also common, especially among small-scale, non-commercial farmers in rural areas who produce tilapia mainly for family subsistence. Feeding is carried out once or twice daily, depending on fish size and pond conditions. Manual feeding is the most common feeding method in all SSA countries. However, the use of automatic feeders or demand feeders has been successfully tested in tilapia cage culture in Ghana and Malawi. The main constraints faced by tilapia farmers and the tilapia feed industry in SSA include the escalating price of ingredients and finished feeds, high transportation costs, poor transport and storage infrastructure, limited commercial feed production due to low demand, poor quality of locally produced feeds and limited research on tilapia feeds and feeding under local conditions. In order to tackle these problems, the SSA governments should: stimulate domestic feed industries by reducing or removing taxes on imported feed milling machinery and basic feed ingredients, provide low-interest loans to producers, ensure feed quality and safety through inspections and feed certification, promote the adoption of appropriate feed manufacturing guidelines and standards, provide the necessary extension services and training on the best feeding and fertilization practices, develop country-specific farm-made feed formulations and promote research on tilapia nutrition and feed management, with emphasis on nonconventional feed ingredients. On the other hand, commercial feed producers should produce and market necessary feedstuffs to fish farmers, provide high-quality feeds at reasonable prices, make proximate analyses available to clients and provide information on feed availability and efficacy to the public sector.

1. INTRODUCTION

Tilapias are a group of freshwater fish species originating exclusively from Africa (Philippart and Ruwet, 1982; El-Sayed, 2006). They are distributed throughout Africa, except for the northern Atlas Mountains and southwest Africa (McAndrew, 2000). Outside Africa, tilapia were introduced into many tropical, subtropical and temperate regions of the world during the second half of the twentieth century (Pillay, 1990; El-Sayed, 2006). Tilapia can live in various ecological systems, including slow-moving rivers and their flood-plain pools and swamps, small shallow lakes, large deep lakes, impounded waterbodies, isolated crater lakes, soda lakes, thermal springs and brackishwater lakes (Philippart and Ruwet, 1982; Lowe-McConnell, 2000). They have many attributes that make them ideal candidates for aquaculture, including their fast growth, tolerance to a wide range of environmental conditions (e.g. temperature, salinity, low dissolved oxygen, etc.), resistance to stress and disease, ability to reproduce in captivity, short generation time, feeding at low trophic levels and acceptance of artificial feeds immediately after yolk-sac absorption.

It is believed that tilapia culture was practiced in Egypt about 4 000 years ago, as illustrated from ancient Egyptians tombs (Balarin and Hatton, 1979). Tilapia culture has rapidly expanded throughout the world in recent years, so that tilapia are currently cultured in about 100 countries. As a result, the global production of farmed tilapia has increased more than 900 percent during the past two decades, jumping from 383 654 tonnes in 1990 (representing 2.28 percent of total aquaculture production) to reach 3 497 391 tonnes in 2010 (4.43 percent of total production). The average annual growth of tilapia production during that period approached 13 percent. Thus, tilapia rank second in terms of global production, after carps (Fitzsimmons, 2008).

Tilapia have been traditionally cultured semi-intensively, at small-scale levels, in different parts of the world, either in monoculture or in polyculture with other herbivorous/omnivorous fishes, such as carps and mullets. However, the rapid industrialization of tilapia production in recent years has led to a gradual shift from low-input, semi-intensive culture (SIC) to more intensive farming practices, with an increasing dependence on formulated feeds (El-Sayed, 2006, 2007).

Therefore, the major challenge facing the tilapia culture industry is the production of sufficient amounts of quality seed. The formulation of appropriate feeds in order to optimize reproductive outputs, seed production and growth performance is also a key factor for promoting tilapia culture. Commercial tilapia culture is currently restricted to about 10 species. However, Nile tilapia (*Oreochromis niloticus*) (particularly all-male fish) is the most important farmed tilapia species globally. The production of farmed Nile tilapia represented more than 75 percent of the total production of farmed tilapia in the period 1970 to 2010.

2. TILAPIA CULTURE IN SUB-SAHARAN AFRICA

Geographically, sub-Saharan Africa (SSA) is the area of the African continent which lies south of the Sahara. It includes 46 countries (Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Togo, Uganda, United Republic of Tanzania, Zambia and Zimbabwe). The Horn of Africa and Sudan are geographically part of sub-Saharan Africa, but they are also part of the Arab world. The sub-Saharan region is characterized by an extremely harsh climate.

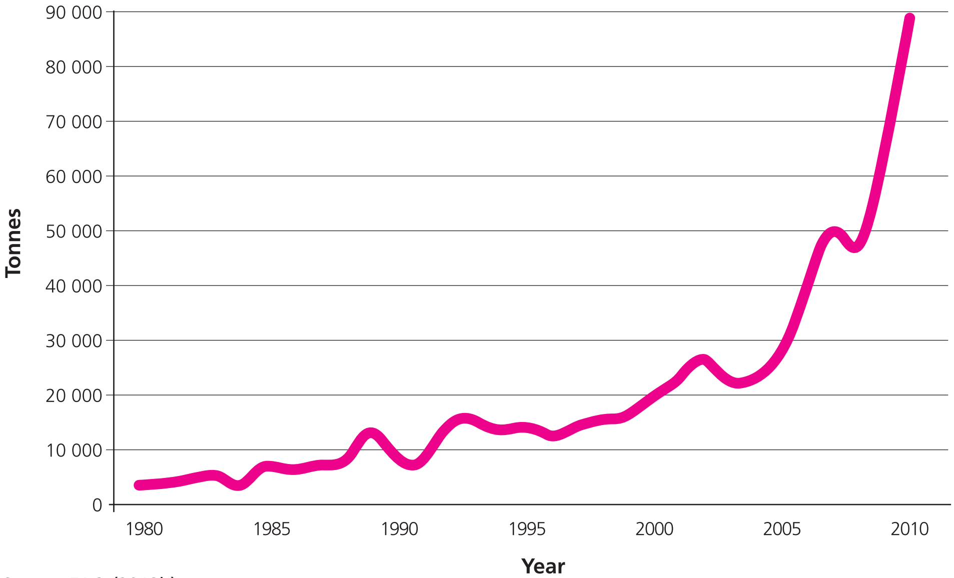
Aquaculture in SSA dates back to the 1920s, when trout breeding was introduced into Kenya and Madagascar, and later into Tanzania**.** However, in spite of this long history, aquaculture still remains marginalized, with limited contribution to national economies. Aquaculture in SSA contributes 0.63 percent and 34.95 percent to total world and African aquaculture production, respectively (FAO, 2012b).

Tilapia have been, and still are, the target species for aquaculture in many sub-Saharan countries. These fish make a significant contribution to food security in rural areas. Small-scale non-commercial tilapia farms vastly outnumber commercial farming enterprises. Despite the fact that tilapia are African fish, tilapia culture in SSA is relatively new, with a low contribution to both global and African tilapia production (2.5 and 13.7 percent, respectively in 2010; FAO, 2012b). Farmed tilapia production in SSA, however, has sharply increased during the past few years (Figure 1). Generally, this trend in tilapia production can be divided into three phases:

- **1980–1995**: during this period, the production of tilapia grew slowly and intermittently.
- **1996–2005**: tilapia production soared to 27 630 tonnes by 2005**.**
- **2006–2010**: tilapia production witnessed a huge increase, reaching 88 238 tonnes by 2010. Further increase in production is expected, due to the expansion of tilapia culture in several SSA countries.

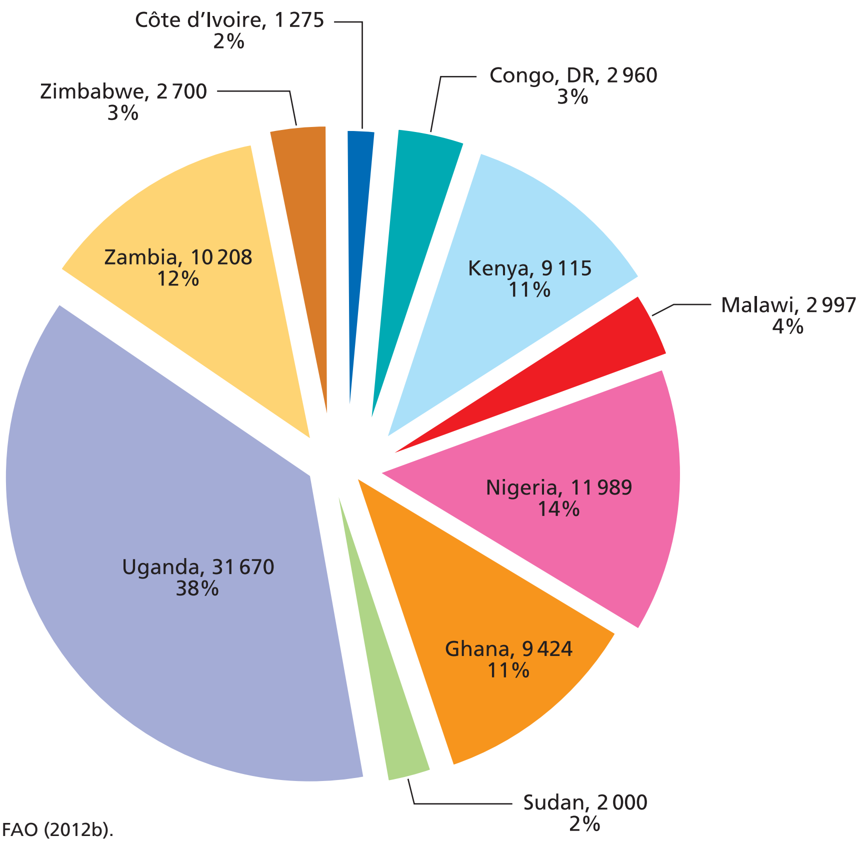
This review can be considered a sequel to previous studies undertaken in 2001 (Shipton and Hecht, 2005) and 2007 (Hecht, 2007). However, this review is more specific, since it focuses on feed management practices for tilapia alone, not the whole aquaculture sector in SSA. For comparison and where appropriate, information on tilapia feeding and feed management from other African countries is also presented. This review has considered only the SSA countries whose annual tilapia production exceeds 500 tonnes per year: Côte d'Ivoire, DR Congo, Ghana, Kenya, Malawi, Nigeria, Sudan, Uganda, Zambia and Zimbabwe. The tilapia production of these countries represents 95 percent of total tilapia production in the region; the proportion produced by each of these ten countries in 2010 is shown in Figure 2.

FIGURE 1
Production of tilapia in sub-Saharan Africa, 1980–2010



Source: FAO (2012b).

FIGURE 2
Tilapia production by the ten major producing countries in the sub-Saharan Africa region in 2010



Source: FAO (2012b).

2.1 Cultured tilapia species

In all selected sub-Saharan countries, except Malawi, Nile tilapia (*Oreochromis niloticus*) is the dominant cultured cichlid species (Table 1). Nile tilapia has been excluded from Malawian waters and replaced with Mozambique tilapia (*O. mossambicus*), chambo (*O. shiranus shiranus* and *O. karongae*) and redbreast tilapia (*Tilapia rendalli*). Longfin tilapia (*O. macrochir*) and redbreast tilapia are also widely cultured elsewhere, particularly in DR Congo, Rwanda, Togo, Zambia and Zimbabwe. The culture of other tilapia species is limited and scattered in a few countries.

2.2. Major producers

In 2010, 39 sub-Saharan African countries reported production of farmed tilapia; however, the production of some countries is small (<100 tonnes per year). Ten countries (Côte d'Ivoire, Democratic Republic of the Congo, Ghana, Kenya, Malawi, Nigeria, Sudan, Uganda, Zambia and Zimbabwe) contribute over 95 percent of the total amount of tilapia produced in the African continent, ranging from 87 to 96 percent during 2000 to 2010 (Table 2, Figure 3). However, the major African producer is a non SSA country, Egypt, which produced 86.3 percent of the total African tilapia production in 2010 (FAO, 2012b). The contribution of tilapia to total aquaculture production in the selected ten countries is substantial, ranging from 75 to 100 percent, with the exception of Nigeria and Uganda, where the contribution of tilapia was only 6 and 33 percent, respectively, in 2010 (Table 3). Tilapia production from freshwater environments dominates, representing over 99 percent of total tilapia production in the SSA Region.

Tilapia culture in SSA countries has been growing at an outstanding rate during the past five years, with an overall annual growth rate of 23.46 percent between 2006 and 2010. Moreover, tilapia culture in Uganda, Nigeria, Zambia, Kenya and Ghana is growing at much higher rates than the regional average. In fact, these five countries produced 31 670, 11 989, 10 208, 9 115 and 9 424 tonnes, respectively, representing 82 percent of total tilapia production in SSA countries (35.9, 13.6, 11.6, 10.3 and 10.7 percent, respectively) in 2010.

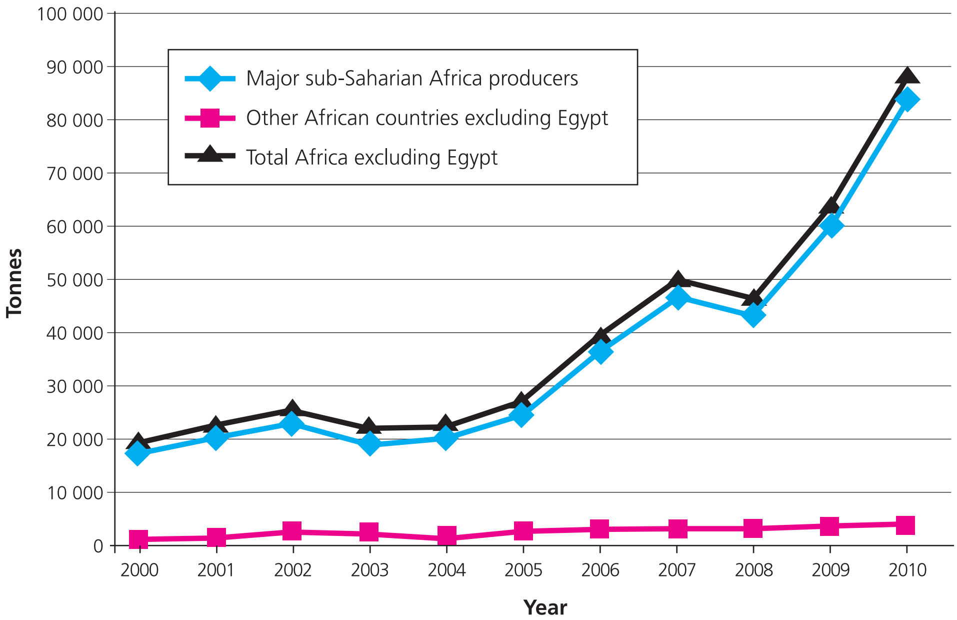
TABLE 1

Tilapia species cultured in sub-Saharan Africa

Species	Côte d'Ivoire	DR Congo	Ghana	Kenya	Malawi	Nigeria	Rwanda	Sudan	Togo	Uganda	Zambia	Zimbabwe
Nile tilapia (*Oreochromis niloticus*)	x	x	x	x		x	x	x	x	x	x	x
Blue tilapia (*O. aureus*)	x											
Mozambique tilapia (*O. mossambicus*)					x							
Three spotted tilapia (*O. andersonii*)											x	
Longfin tilapia (*O. macrochir*)		x					x		x		x	x
Chambo (*O. shiranus shiranus*)					x							
Chambo (*O. karongae*)					x							
Banded jewel fish (*Hemichromis fasciatus*)												
Redbelly tilapia (*Tilapia zillii*)										x		
Redbreast tilapia (*T. rendalli*)		x			x		x				x	x
Guinean tilapia (*T. guineensis*)			x									
Blackchin tilapia (*Sarotherodon melanotheron melanotheron*)	x		x						x			
Mango tilapia (*Sarotherodon galilaeus galilaeus*)			x								x	

Source: El-Sayed (2006); Hecht (2007).

FIGURE 3
Tilapia production by major producing countries in sub-Saharan Africa 2000–2010



Source: FAO (2012b).

TABLE 2
Total tilapia aquaculture production (tonnes) by the ten major producers in sub-Saharan Africa (SSA), 2000–2010 and their contribution to SSA tilapia production

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Côte d'Ivoire	967	870	725	706	706	706	661	1 050	1 050	1 050	1 275
Democratic Republic of the Congo	2 073	2 738	2 959	2 959	2 959	2 959	2 960 D	2 960	2 960	2 960	2 960
Ghana	3 712	4 400	4 400	285	760	954	2 000	3 500	5 100	6 676	9 424
Kenya	222	412	421	600	614	622	609	2 965	3 113	3 424	9 115
Malawi	500	532	620	630	697	767	1 445	1 445	1 656	1 500	2 997
Nigeria	2 705	2 626	4 496	3 948	4 176	6 144	9 216	9 272	3 223	10 218	11 989
Sudan	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 350	1 350	2 000	2 000
Uganda	600	1 550	1 957	2 200	1 660	4 239	11 388	16 891	17 130	21 573	31 670
Zambia	4 020	4 370	4 530	4 455	5 080	5 080	5 080	5 080	6 504	8 437	10 208
Zimbabwe	2 041	2 165	2 213	2 600	2 950	2 450	2 450	2 450	2 450	2 650	2 700
Total of 10 major producers	17 840	20 663	23 321	19 383	20 602	24 921	36 809	46 963	43 645	60 488	84 338
Total SSA tilapia production	19 526	22 594	26 244	22 224	22 677	27 630	39 883	50 305	46 694	63 776	88 238
% contribution of the ten major producers to SSA total tilapia production	91.4	91.5	88.9	87.2	90.9	90.2	92.3	93.4	93.5	94.8	95.6

Source: FAO (2012b).

TABLE 3

Tilapia production (tonnes) and contribution to total aquaculture production in the ten selected SSA countries in 2010 (tonnes)

Country	Congo, DR	Côte d'Ivoire	Ghana	Kenya	Malawi	Nigeria	Sudan	Uganda	Zambia	Zimbabwe
Tilapia production	2 960	1 275	9 424	9 115	2 997	11 989	2 000	31 670	10 208	2 700
Total aquaculture production	2 970	1 700	10 200	12 154	3 163	200 535	2 200	95 000	10 290	2 702
% of tilapia in total aquaculture production	99.7	75.0	92.4	75.0	94.8	6.0	91.0	33.3	99.2	100.0

Source: FAO (2012b).

2.3 Tilapia culture systems in SSA

Tilapia culture in all SSA countries is categorized by the level of intensity (i.e. extensive, semi-intensive, intensive) with respect to culture systems, species cultured, the intensity of management inputs, labour requirements, feeding and fertilization levels and level of integration with other agricultural/animal production activities.

2.3.1 Non-commercial, extensive culture

Non-commercial, extensive tilapia culture is considered a small-scale, low input-low output activity. It is practiced in earthen ponds, varying in size, depth and ownership. Typically, a farmer owns between one and five ponds with a size range of <100 m^2 to 1 000 m^2 (Quagrainie *et al.*, 2005; Hecht, 2007; Chimatiro and Chirwa, 2007). Family labour is generally used, while the use of hired labour is very rare because many small-scale farmers do not have the cash to hire external labour. Pond depth ranges from <50 cm to >1 m.

Monoculture of tilapia (*O. niloticus* and *Tilapia* spp.) is commonly practiced in most of the selected countries. However, polyculture of tilapia with North African catfish (*Clarias gariepinus*) and common carp (*Cyprinus carpio*) is also practiced in Côte d'Ivoire, Malawi, Kenya, Nigeria, Uganda and Zambia. Typically, mixed-sex tilapia is used, although sex-reversed (all male) tilapia culture is becoming widespread in a number of countries (Côte d'Ivoire, Ghana, Kenya, Uganda and Zambia).

Non-commercial, rural/subsistence tilapia culture in SSA countries, especially in Cameroon (Pouomogne, 2007), Kenya (Nyandat, 2007), Malawi (Chimatiro and Chirwa, 2007) and Uganda (Rutaisire, 2007) is primarily based on a fertilization system using a compost crib built inside the pond. The crib varies in size among countries depending on the pond size. In Cameroon, for example, the crib is a bamboo frame occupying about 10 percent of the pond water surface. Prior to stocking the pond, the crib is filled with different inputs that are available on the farm (e.g. weeds, leaves, green fodder, grass, animal manure and household food wastes). The contents are turned and mixed biweekly, the nutrients released from the crib stimulating natural productivity in the pond. In this way, cultured fish (mainly Nile tilapia) depend exclusively on the natural food production of the waterbody.

Stocking densities of tilapia fingerlings in this system are generally low, ranging from 1–4/m^2. Fingerlings are either collected from the wild or bought from hatcheries (ADiM, 2005; Hecht, 2007). Non-commercial, extensive tilapia culture in SSA is generally integrated with horticulture and/or animal production activities.

2.3.2 Semi-intensive culture

Semi-intensive, small-scale tilapia culture is the most popular farming system in SSA. Both monoculture (mainly Nile tilapia) and polyculture systems are currently in use. More than 95 percent of the farmers in Tanzania culture mixed-sex Nile tilapia in earthen ponds in monoculture (Quagrainie *et al.*, 2005). Farmers use naturally available feeds, through pond fertilization. However, polyculture systems of *O. niloticus* (or other tilapia species; e.g. *O. shiranus* and *O. mossambicus* in Malawi and *O. andersonii* in Zambia) with *C. gariepinus* or other clariids such as *Heterobranchus* spp. is gaining popularity, particularly in Nigeria, Cameroon, Ghana, Kenya and Uganda, because of the higher yields (Hecht, 2007). Stocking densities in semi-intensive systems generally range from 1 to 4/m². Fishponds are usually stocked using fingerlings left over at harvest or purchased from neighbours (ADiM, 2005).

Pond preparation and management

Semi-intensive tilapia culture is practiced exclusively in earthen ponds. The majority of semi-intensive tilapia farmers in all selected countries pay little attention to pond management practices, in terms of scheduled stocking, fertilization, feeding and harvesting (Hecht, 2007). In Kenya and Tanzania, for example, one person in each household is responsible for managing the fishponds. The management includes pond maintenance, feeding, harvesting and marketing the fish (Quagrainie *et al.*, 2005).

During pond preparation in Malawi, the ponds are dried for two to three weeks or until the soil cracks. Afterwards the ponds are limed to neutralize the soil pH and to eliminate bacteria, parasites and other pathogens. About 3–4 tonnes/ha of cattle manure and 2 tonnes/ha of chicken manure are generally applied. The water is then added and the ponds are left for 7–10 days before the fish are stocked. After a month, if the colour of the water is not yet green, nitrogen : phosphorus : potassium (NPK) fertilizer is applied to boost plankton production. This is done on an annual basis. Pond preparation in Cameroon is performed using quick lime (10 to 30 kg per 100 m² water surface, depending on the nature of the pond bottom and the experience of the farmer (Pouomogne, 2007).

Pond fertilization

In semi-intensive tilapia culture systems in SSA, both organic and inorganic fertilizers are used for pond fertilization. However, the use of fertilizer is constrained by availability, price, transport and cash resources. The majority of non-commercial small farmers use compost and organic fertilizers (animal manure) if available. Meanwhile, small and large-scale commercial farmers use animal manure regularly, and also use chemical fertilizers if necessary. Poultry droppings are the most commonly used manure throughout the SSA Region. Cattle manure is also widely used in some countries. In Malawi, Nigeria, Ghana and Cameroon, chicken manure is most commonly used. On the other hand, about 60 percent of tilapia farmers in Uganda use cattle manure, while chicken manure was least used.

The fertilization rate for organic fertilizers ranges from 2 to 9 tonnes/ha (Table 4). However, it has been reported that actual fertilization rates in some countries are generally lower (<30 percent) than the recommended rates (Hecht, 2007), such as Cameroon (Pouomogne, 2007) and Ghana (Abban, 2005). Generally, tilapia farmers spread dry fertilizer on the pond bottom before filling with water. Other farmers pile the dry manure on farm dikes and spray it with water for few days before washing it into the ponds. This process enhances decomposition and reduces the time needed to achieve maximal primary production in the ponds, compared with dry manure.

TABLE 4

Examples of pond fertilization regimes used in tilapia culture in sub-Saharan Africa

Species (country)	Size (g)	Density (fish/ha)	Fertilization regime	Feeding	Culture period (day)	Yield (tonnes/ha/year)	Remarks	Reference
Oreochromis niloticus (Cameroon)	200–222	7 600	Cattle manure, 226 kg dry wt/ha/day	Cotton seed cake 3% BW*/day, 6% BW/day	100	4.80–6.50	Polyculture with *Clarias gariepinus* (1 100 fish/ha) as police-fish.	Middendorp (1995)
♂ *O. niloticus* (Kenya)	90	1 000	Di-ammonium phosphate (DAP) + urea, 20 kg N/ha/week		133	1.72**	During warm season (23.5–28.2 °C)	Veverica, Bowman and Popma (2001)
♂ *O. niloticus* (Kenya)	16.9	1 000	DAP + urea, 20 kg N/ha/week		147	2.95**	During cool season (22.5–26.4 °C)	Veverica, Boman and Popma (2001)
O. niloticus (Kenya)	45	17 000	DAP and urea (20 kg N/ha and 8 kg P/ha) weekly	Shrimp meal diet at 0, 6 and 12%, 2% BW/day	250	4.10–4.60	Animal protein not necessary in feeds of Nile tilapia raised in fertilized ponds; FCR: 1.3:1	Liti *et al.* (2006a)
T. rendalli (Malawi)	18	20 000	Chicken manure (500 kg/ha/week), pig manure (500 kg/ha/week), cattle manure (1 200 kg/ha/week)		84	0.58–1.26	Chicken manure was best	Kang'ombe, Brown and Halfyard (2006)
T. rendalli (Malawi)			3–4 tonnes of cattle manure and 2 tonnes of chicken manure per ha, NPK fertilizer is applied when needed	Farm-made feed, hand fed, once or twice daily		8.9		Longwe, Kang'ombe and Kaunda (2010)
♂ *O. niloticus* (Kenya)	21	20 000	Urea (20 kg N/ha) and DAP (8 kg P/ha) weekly	Wheat bran, local diets, pig diets; twice per day, 2% BW/day	258	6.20–7.70	*C. gariepinus* (1 000 fish ha) used as police-fish; formulated feed was best; wheat bran was most economic; FCR: 2.6:1–3.0:1	Liti *et al.* (2005)
O. niloticus (Kenya)	14	19 462	Urea (20 kg N/ha) and DAP (8 kg P/ha) weekly	Rice bran, wheat bran, maize bran	250	1.29–2.04**	*C. gariepinus* (250 fish/ha) stocked; maize bran produced highest yield; wheat bran was most cost-effective	Liti *et al.* (2006b)

*BW = body weight;
**Production (tonnes) per culture period provided.

Source: see reference column.

In Malawi, tilapia ponds are fertilized during preparation, and afterwards at monthly intervals. Fishponds are fertilized with composted manure or with poultry, goat and/or cattle manure. Tilapia are also fed with on-farm agricultural by-products, such as maize or rice bran, if available (Chimatiro and Chirwa, 2007).

Animal manure (pig, chicken and duck) is also widely used in Kenya in tilapia production in earthen ponds. The quality of manure as a fertilizer varies depending on the source animal and the quality of feed fed to the animal. Application rates depend on the size of the pond, stocking density and water productivity. Generally, a fertilization rate of 5 kg/100 m^2/week is used. Manure is applied using the following methods:

- Crib method, where a compost crib is constructed using wooden sticks at one or more sides of the pond. The manure in the crib is frequently mixed to facilitate the gradual release of nutrients into the pond.
- Bag method, where a bag is filled with manure and tied to the corner of the pond. The bag is shaken weekly or daily to release nutrients.

In Cameroon, small-scale commercial tilapia farmers use single feed ingredients to feed their fish along with pond fertilization. This practice is often integrated with domestic animal production (mainly chickens or pigs). Normal stocking density is 1 to 2 tilapias plus 1 catfish per m^2, plus some other fish species at a lower density. Higher production levels have been recorded when the number of species in the pond is increased and feeding and pond fertilization are adequate.

Supplemental feeding

Tilapia farmers in the selected countries use a variety of feed inputs, depending on fish size, stocking density, water productivity and culture system. The inputs range from single feed ingredients such as maize bran, corn bran, wheat bran and rice bran to farm-made feeds. They also used kitchen leftovers and leaves. Feeding regimes also vary from one country to another. In Malawi, for example, *T. rendalli* and *O. shiranus* are fed by the broadcasting method, where the feed is sprinkled into the ponds by hand. Feed is offered once or twice daily, depending on the production stage. Fingerlings are fed twice daily (around 07.00 and between 12.00 and 13.00), while fish in fattening ponds are fed only once a day.

The production levels in semi-intensive pond systems vary considerably from one country to another, depending on tilapia species, stocking size and sex, culture inputs, farming system and duration of the production cycle. Therefore, production ranges from less than one tonne/ha/year to over 7 tonnes/ha/year (Table 4). Polyculture of Nile tilapia and North African catfish is commonly practiced throughout the region.

Commercial tilapia culture in earthen ponds

Commercial aquaculture in earthen ponds is well developed in Nigeria and Zambia. In many of the selected countries, polyculture of *O. niloticus* and *C. gariepinus* is currently the most popular practice, although some farmers use other combinations. While polyculture is practiced in all countries, commercial farmers in several countries also produce *O. niloticus* (Zambia and Kenya) and *C. gariepinus* (Nigeria) under monoculture farming conditions. Production levels range from 2.5 to 15 tonnes/ha/year for *O. niloticus* (monoculture) and *O. niloticus/C. gariepinus* polyculture, and up to 10–30 tonnes/ha/year for *C. gariepinus* monoculture in Nigeria (Hecht, 2007). The size of the production ponds ranges from 500 m^2 to 1.5 ha. Stocking densities in earthen ponds average around 5–8 fingerlings/m^2.

The majority of tilapia farmers feed their fish manually with farm-made feeds or commercial pellets. However, automated feeding systems (Figure 4) are being investigated in Zimbabwe to deal with the expected growth and high tilapia biomass anticipated in the coming years (Pasipamire, 2009).

FIGURE 4
Feeding tilapia ponds in Zimbabwe using mechanical blower

COURTESY OF W. PASIPAMIRE.

Tilapia-rice farming

The potential of tilapia culture in rice fields has been investigated (Kabré, 2000; Miller, 2006; Sanni and Juanich, 2006) and appears very high, especially in Mali, Burkina Faso, Senegal, Côte d'Ivoire and Ghana. Oswald, Copin and Monteferrer (1996) reported positive interactions and returns from the farming of Nile tilapia in ponds adjacent to lowland rice fields in peri-urban zones of Côte d'Ivoire. The activity was a suitable farm diversification strategy and benefited from the proximity of markets.

Farming Nile tilapia in rice fields in an integrated system has also been tried in Ghana (Ofori *et al.*, 2005). Fingerlings (25 g average weight) were stocked at 3 000 per hectare in rice fields (refuge pits) 15 days after transplanting. Some of the refuge pits were manured with poultry droppings at 30 kg/ha, whereas supplementary feeding with rice bran was applied to the ponds at a rate of 5 kg/ha/week. The fish were harvested ten days after the rice was harvested. The results indicated that the presence of the fish did not significantly reduce the rice harvest. The percentage increase in revenue from the rice-fish system over rice monoculture ranged from 5 to 11 percent. These results suggest that rice-fish integration could be a viable option for diversification for smallholder rice farmers in lowlands with soil and water conservation structures and a reliable source of water for irrigation.

2.4 Intensive culture

Intensive tilapia culture is practiced in a few SSA countries (Ghana, Kenya, Nigeria, Malawi, Zambia, Zimbabwe and Uganda), mainly in cages and earthen ponds and, to a lesser extent, in tanks and raceways.

2.4.1 Cage culture

In SSA, the contribution of tilapia production from cages is relatively low and varies between countries (Jamu, 2001, El-Sayed, 2006). Nile tilapia and chambo (*O. shiranus* and *O.karongae*) are the main species cultured (Blow and Leonard, 2007). Cage culture is currently practiced in Ghana, Kenya, Malawi, Uganda, Zambia and Zimbabwe. Small cages (6 x 6 x 3 m) constructed from locally available materials are generally used in many of the ten selected countries. In addition, commercial, medium- to large-scale cages (800–1 200 m^3) are used in Ghana (Hecht, 2007). Cage culture of tilapia in Africa, especially for small-scale farmers, is affected by the availability and cost of seed and feed, unpredictable water sources and water quality. Table 5 summarizes the cage culture of tilapia in SSA.

TABLE 5

Tilapia cage culture in the sub-Saharan Africa region

Country	Cage size and shape	Tilapia species	Stocking density	Initial size (g)	Feed and feeding	Period (month)	FCR	Harvest size (g)
Ghana (Crystal Lake)[1]	Circular, 32 m dia, 5 m depth	*Oreochromis niloticus*	100 000 fish/cage (0.5–1.0 kg/m^3)	5–8	Powdered feed	2		40–50
Ghana (Crystal Lake)[1]	Circular, 32 m dia, 5 m depth	*O. niloticus*	50 000–60 000	40–50	Extruded, sinking pellets	3	1.7:1–2.2:1	250
Ghana (Volta Lake)[2]	6×4 m on the sides, 2 m deep (48 m^3)	*O. niloticus* all-male and mixed sex	63–188 fish/m^3	10–30	Imported floating pellets (28–32% CP), manual feeding, 2–3 times/day	6	1.4:1–2.5:1	250 (mixed sex) 400 (all-male)
Kenya (Harambee Dam, Nyanza)[3]	Rectangular, 0.64 m^3	All-male tilapias	130	20	30% CP, farm-made, semi-floating, 6% BW/day	7		285
Uganda (Lake Victoria)[4]	2x2x2 m		2 400	15–18	On-site, sinking feed, demand feeders	12		700
Ethiopia (Lake Kuriftu)[5]	1x1x1 m	*O. niloticus*	50	46	Mill sweeping, cotton seed, and Bora* food complex at 2% BW/day, feeding trays	5	2.48:1	220
Zimbabwe (Lake Kariba)[6]	Cylindrical, 1 000 m^3, 17 m diameter	*O. niloticus*			Pellets (sinking and floating) and crumb-based feeds, 30–45% CP, 1.7-3.0% BW/day	7		690
Malawi (Maldeco Ltd, Lake Malawi)[7]		*O. shiranus*	65–75/m^3	30	Local, low quality	6–9		20–40 kg/m^3
Kenya (Dominion Farms Ltd)[7]	Square (4 m^3)	*O. niloticus*			Imported pellets			200 kg/m^3

Notes: CP = crude protein, BW = body weight; FCR = feed conversion ratio

*Bora is a local feed plant, produce cattle feed from nut cake, wheat bran and corn bran

Source: [1]Blow and Leonard (2007); [2]Ofori *et al.* (2009); [3]Charo-Karisa (2009); [4]Gatward (2009); [5]Gibtan, Getahun and Mengistou (2008); [6]Pasipamire (2009); [7]Hecht (2007).

The largest and most successful commercial farm for cage culture of tilapia (Lake Harvest) is located on Lake Kariba, Zimbabwe (Figure 5). The farm includes 14 cylindrical cages, each cage (bag-net) having a volume of 1 000 m^3 and a diameter of 17 m. The total production of the farm is about 3 000 tonnes/year. The facility is also provided with a very high-standard processing unit. The tilapia produced are exported, either as fresh fillets or frozen, to Europe and the United States of America (Windmar, Jarding and Paterson, 2000; El-Sayed, 2006). The fish are fed with commercial extruded pellets made in Zimbabwe for Lake Harvest.

FIGURE 5
Feeding tilapia in cages in Lake Kariba, Zimbabwe

COURTESY OF W. PASIPAMIRE.

A similar cage farm consisting of 32 cages has been established in Lake Malawi (Malawi), with a target production of 3 000 tonnes of chambo (*O. karongae* or *O. shiranus*). Initial stocking density ranges from 65 to 75 fingerlings per m^3 (30 g average weight). After a rearing cycle of about six to nine months, final harvest ranges from 20 to 40 kg/m^3.

Cage-cultured tilapia are generally fed with farm-made, sinking feed. Feed is dispensed by hand two to three times a day (morning, midday and/or late afternoon). The feeding regime is planned and quantities measured in advance to make sure that fish have optimum growth and the best possible FCR. However, the large-scale tilapia cage farm in Lake Kariba, Zimbabwe feed the fish 30 to 45 percent crude protein (depending on developmental stage) sinking and floating pellets and crumbles (Pasipamire, 2009). The FCR of cage-cultured tilapia ranges from 1.4:1–2.5:1, depending on fish size, stocking density, and feed type and quality

Although floating feeds are preferred, they are expensive to produce and not yet available on a commercial scale in Uganda. However, a number of companies have started producing floating/extruded pellets on a relatively small scale. In addition, imported feeds have been tried at some locations in Uganda, but they are expensive and thus not economically viable for large-scale commercial farms.

2.4.2 Tank and raceway culture

Tilapia culture in concrete tanks and raceways is very limited and is practiced in only a few countries. In Kenya and Zambia, circular and 'D-ended' concrete tanks are used for the production of Nile tilapia (Hecht, 2007). The size and shape of tilapia culture tanks vary depending on the culture objectives. Fry and nursery tanks are generally small (<2 to 10 m^3) (Figure 6), while production tanks are much larger. Fish are fed farm-made pellets or commercial feeds twice a day (morning and afternoon); younger fish are fed more frequently. Tilapia ponds are often aerated with paddle wheels or blowers, where appropriate.

FIGURE 6
Concrete tanks for nursing Nile tilapia, Lake Harvest, Zimbabwe

3. ON-FARM TILAPIA FEED MANUFACTURING

The vast majority of non-commercial/semi-intensive tilapia farms in SSA rely on farm-made feeds. In Nigeria, for example, about 70 percent of the tilapia feeds used is farm-made (dry mash, dough balls and meat-mincer pellets, fed in moist or sun-dried form) (Ayinla, 2007). This is mainly because small-scale commercial farmers cannot afford manufactured pelleted feeds. About 100 000 tonnes of farm-made feeds are currently produced annually in the region (Hecht, 2007). On the other hand, about 20–30 percent of commercial fish production is attributed to industrial aquafeeds. The main protein sources of farm-made feeds are oilseed cakes (cotton, soybean and sunflower), fishmeal, blood meal, carcass meal, brewer's waste, groundnut cake, palm kernel cake, and poultry by-product meal. Energy sources include cereal bran, corn, kitchen waste and vegetables. Farm-made feed formulations vary by country and season, depending on availability and price of ingredients and the culture system adopted. These formulations range from single feed ingredients, such as wheat bran, rice bran or ground corn, to formulated mixes, moist feed cakes and processed, dry pellets. Farm-made feed production depends mainly on trial and error and is based on limited scientific knowledge. Therefore, further nutritional research is urgently needed in the SSA Region. Typically, local feed formulation includes the following steps:

- sourcing of ingredients (mainly locally available);
- grinding (using a hammer mill) (Figure 7);
- mixing (manually in most cases, using a shovel, to ensure proper blending);
- pelleting, using locally produced pelleting machines operated by diesel engine, electricity (Figure 8) or manually;
- drying (mostly sun-drying, occasionally oven-drying or the use of a kiln); and
- storing (on farm dykes or in stores).

These feeds are made using easy and simple techniques. The feedstuffs are milled and mixed at predetermined ratios. Mixing is done by hand or with the use of mechanical mixers. Some of the ingredients, such as soybean meal and maize meal, are precooked to get rid of the antinutrients they may contain (i.e. protease inhibitors, gossypol and haemagglutinin) and to improve the binding capacity and digestibility of the feed. Warm water is gradually added to the mixture, with continuous mixing until a firm dough is obtained. Moist strands are extruded using a hand or electrically operated meat mincer or pasta maker (Figure 8). The strands are sun-dried or oven-dried, broken up into appropriate sizes, and stored.

FIGURE 7
Ingredient grinder in Ghana

COURTESY OF N. AGBO.

FIGURE 8
Making on-farm aquafeed in Nigeria

COURTESY OF K. JAUNCEY.

Farm-made feeds in SSA are generally characterized by their poor quality, high price and inconsistent production rate. These feeds also have common problems throughout the region. Many small-scale farmers do not add micronutrients such as vitamin and mineral mixes and antioxidants to diet formulations. This practice leads to considerable reduction in storage time and the acceleration of spoilage. Another major problem associated with farm-made feeds is the high content of fines, which leads to feed wastage and poor FCR. It is no surprise, therefore, that the FCR of locally produced tilapia feeds ranges from 0.95:1 to >6:1 (Liti *et al.*, 2005; Hecht, 2007; Pouomogne, 2007; Rutaisire, 2007; Nyandat, 2007; Chimatiro and Chirwa 2007). The formulation and protein content of tilapia feeds (both farm-made and industrial feeds) in different countries of the SSA region are summarized in Table 6.

TABLE 6

Formulation (percent) and protein content (see notes) of farm-made and industrial tilapia feeds in various countries of the sub-Saharan Africa Region

Ingredient	Grower[1]	Grower[2]	Grower[3]	Grower[4]	Industrial[5]	Industrial[6]	Starter/ broodstock[7]	Industrial[8]	Fingerling[9]	Grower[9]	Finisher[9]
Fishmeal		20		15	16	11	30	15	32.69	32.69	24.4
Blood meal						13.5	5				
Carcass meal							15				
Bone meal	1										
Shrimp meal											
Soybean meal				45			15	45			
Soybean cake	13	15				3					
Cotton seed cake	15	15			17	4			10	10	10
Groundnut cake	12	5									
Sunflower cake			30								
Copra cake					17						
Brewery waste	10	15									
Rice/wheat bran	20	15				8			18		
Wheat bran					50				35	35	35
Rice bran										18	18
Wheat flour							22				
Maize bran			50			7	10.5				
Cocoa husk	10										
Layer droppings meal	15										
Pigeon pea meal			20								
Cassava flour						4					
Maize		8		25		49		25	2.8	2.8	2.8
Maize germ											
Palm oil	2	2									
Vegetable oil				6				6			
Fish oil				4				4			
Starch/binder				2				2			
Vitamin and mineral premix	2	5		3		0.5	2.5	3	0.5	0.5	0.5
Shell									0.39	0.38	1.71
Salt									0.23	0.23	0.47
DL-Methionine									0.04	0.04	0.02
L-Lysine									0.35	0.35	0.10

[1] 31% crude protein (CP), for semi-intensive Nile tilapia in fertilized ponds (Cameroon) (Hecht, 2007); [2] 35% CP, for Nile tilapia in fertilized ponds (Cameroon) (Hecht, 2007); [3] 20% CP, for common carp and Mozambique tilapia in fertilized ponds (Malawi) (Hecht, 2007); [4] 38% CP, for Nile tilapia (Nigeria) (Hecht, 2007); [5] 25% CP, industrial tilapia feed (Kenya) (Nyandat, 2007); [6] Industrial pellets for Nile tilapia and North African catfish in polyculture (Cameroon) (Hecht, 2007); [7] 37% CP, for catfish, carp and tilapia fingerlings and broodstock (Malawi) (Chimatiro and Chirwa, 2007); [8] 30% CP, tilapia feed (Nigeria) (Ayinla, 2007);
[9] Moehl and Halwart (2005), (Côte d'Ivoire): fingerlings (1–30 g, 32% CP); grower (30–100 g; 32% CP); and finisher (100–500 g, 28% CP).

Tilapia feeding practices also vary widely. Non-commercial farmers feed their fish at irregular intervals, depending on the availability of resources and by-products. Feeding practices also vary by country depending on the level of extension and knowledge of the farmer (Nyandat, 2007). Cereal bran is broadcast over the water surface by hand, while kitchen and fruit wastes, vegetables, grass and maize stovers are placed into the pond cribs. Supplemental feeding is provided mainly by hand, two to three times per day, whereas demand feeders are rarely used.

Small and large-scale commercial tilapia farmers in Malawi apply the feed in the form of a moist mash in feeding bags or on trays, or in pelleted form (Chimatiro and Chirwa, 2007). The fish are fed on a regular basis once or twice per day depending on average fish size and pond management. Fish in fattening ponds are fed daily, while those in fingerling ponds are fed twice daily (0700 and 1200 to 1300 hours). *Tilapia rendalli* and *Oreochromis shiranus* are fed by the broadcasting method, where the feed is sprinkled into the ponds by hand (Chimatiro and Chirwa, 2007).

4. THE COMMERCIAL AQUAFEED INDUSTRY

The commercial aquafeed industry in the SSA Region is relatively new and is still in the developmental phase. This industry is one of the least developed subsectors of aquaculture in the region (Hecht, 2007). Feed remains one of the major barriers facing the expansion of tilapia culture, especially for medium- and large-scale producers. SSA relies heavily on imported feed ingredients and commercial fish feeds, which makes fish farming expensive, as fish feed accounts for at least 60 percent of the total cost of production. Therefore, only a few countries in the region produce formulated, commercial aquafeeds (i.e. Nigeria, Cameroon, Ghana, Kenya, Malawi, Uganda (Figure 9), Zambia and Zimbabwe) (Hecht, 2007; Gabriel *et al.*, 2007). However, commercial feed production in these countries is limited, and the number of commercial aquafeed mills is low. This has been attributed mainly to the following reasons:

- the demand for commercial fish feed is too low to justify industrial scale production; and
- high production and transportation costs (the cost of commercial tilapia feeds (20–25 percent crude protein) ranges from US$225 to >US$600/ tonne, depending on the country, feed source and composition).

FIGURE 9
Storing and selling commercial fish feed in Uganda

Source: www.sarnissa.org/tiki-browse_gallery.php?galleryId=7

In SSA, where aquafeed is commercially produced there are problems related to consistency of supply and quality. As with farm-made aquafeeds, commercially produced aquafeeds contain substantial amounts of fines (up to 50 percent; Hecht, 2007). Quality control over aquafeed mills is almost absent in most countries of the region. Thus, fish farmers in general and tilapia farmers in particular are forced to rely on farm-made feeds and, to a lesser extent, on imported pelleted feeds. As a result, as stated earlier, the majority of tilapia farmers in SSA make their own feeds on-farm.

5, MAJOR FEED INGREDIENTS

The major feed ingredients that can be used in tilapia feed production are generally available across the SSA Region. However, the status of the existing livestock feed manufacturing capacity, the availability of quality feed ingredients, the availability and accessibility of suitably trained personnel and the presence of favourable legislative and taxation systems are the main indicators of the ability of each country to produce aquafeeds. The increasing competition for feed ingredients among the animal and aquaculture production sectors is expected to increase the prices of feed ingredients and processed aquafeeds. In fact, their prices have already sharply increased over the past few years.

The reported quantities of major feed ingredients produced in SSA that are available for feeding fish and/or manufacturing fish feeds are given in Table 7. Varying quantities of protein sources, especially oilseed sources (i.e. groundnut, soybean, cottonseed, sunflower and sesame seed) are produced in the ten major tilapia farming countries. Similarly, substantial amounts of energy sources, including maize, maize bran, wheat bran, sorghum and millet are produced. Varying amounts of vegetable oils are also produced. This means that the potential of the aquafeed industries in these countries is high. However, the cost of feed ingredients, such as fishmeal and oilseed meals/cakes is a major constraint to the development of aquafeed industries in most places. The price of feed ingredients, particularly fishmeal, oilseed cakes, soybean meal and maize varies highly among countries and seasonally within countries.

The imports and exports of major food/feed commodities in SSA in 2010 are given in Tables 8 and 9. These tables indicate that a short list of varying amounts of plant protein, oil and energy sources are imported to SSA, whereas a longer list of feed ingredients are exported. The prices of these ingredients also vary significantly among the countries of the region and even within the same country, depending on the amounts produced, the quality and the season. For example, the price of imported maize in 2010 ranged from US$329/tonne in Zimbabwe to US$669/tonne in Malawi (Table 8). Similarly, the price of soybean ranged from US$305 (Kenya) to US$1 006 (Malawi). Soybean oil prices fluctuated between US$1 197/tonne (Zambia) and US$2 350/tonne (Malawi).

Countries that have expanding and developing agricultural sectors with surplus production, such as Ghana, Kenya, Malawi, Nigeria, Uganda, Zambia and Zimbabwe, are well placed for the economical production of commercial fish feed. These countries produce surplus amounts of the major feed ingredients and even export varying quantities of these ingredients (Table 9). Kenya, Uganda and Zimbabwe export large amounts of protein (oil seeds and oil seed cakes) and energy (maize and sorghum) sources. In Uganda, for example, soybean cake is exported at US$59/tonne, whereas in Zambia it is exported at US$439/tonne (Table 9). Maize is exported from Uganda at US$214/tonne but at US$1 346/tonne from Ghana. Export prices of wheat bran also ranged from US$37/tonne (Kenya) to US$171/tonne (Sudan).

TABLE 7

Production (tonnes) of major agricultural commodities in the selected sub-Saharan Africa countries in 2010

Commodity	Congo, DR	Côte d'Ivoire	Ghana	Kenya	Malawi	Nigeria	Sudan	Uganda	Zambia	Zimbabwe
Maize	1 156 410	641 610	1 871 700	3 464 540	3 419 410	7 676 850		2 373 500	2 795 480	1 192 400
Rice	317 231	722 609	491 603		110 106	4 472 520		218 111	51 656	
Sorghum			324 422	164 066	53 932	7 140 970	2 630 000	390 779		73 675
Cassava	15 049 500	2 306 840	13 504 100	323 389	4 000 990	42 533 200		5 282 000	1 151 700	204 236
Dry bean				390 598	153 815			455 000		
Vegetable, misc.	370 000			692 461	182 168	5 945 600	525 000	760 000	310 179	157 552
Wheat				511 994			403 000		172 256	50 100
Cocoa bean		1 242 290	632 037							
Coffee, green		94 321						166 968		
Sugar cane	1 950 000	1 650 000	145 000	5 709 590	2 500 000	1 401 680	6 728 000	2 400 000	3 500 000	3 100 000
Millet			218 952			5 170 430	471 000	903 000	47 997	
Groundnut with shell	371 263	90 227	530 887		297 487	3 799 240	762 500	172 000	163 733	106 147
Soybean					73 356			175 000	41 000	57 328
Cottonseed					19 000	228 000	71 000		70 500	69 000
Sunflower seed								230 000		
Sesame seed							350 000	170 000		
Palm oil	187 000	330 000	120 000			1 350 000				
Cottonseed oil	1 836	9 516			4 163	8 800	4 200	5 000	5 833	19 100
Groundnut oil	17 619	2 320	72 168		21 600	850 000	27 032	5 600	3 600	8 700
Palm kernel oil		33 600	16 000			451 177				
Maize oil				13 950						15 300
Sunflower oil							60 083	78 700		3 800
Sesame oil						2 400	63 900	27 700		
Soybean oil						3 600		25 200	3 600	12 500

Source: FAO (2012a).

TABLE 8

Imports of major food/feed commodities in the ten selected sub-Saharan Africa countries in 2010 (quantity in tonnes and price in US$/tonne)

Ingredient	Congo, DR		Côte d'Ivoire		Ghana		Kenya		Malawi		Nigeria		Sudan		Uganda		Zambia		Zimbabwe	
	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price
Wheat	398 751	246	523 461	261	315 838	371	844 559	261	176 822	685	3 971 861	263	1 843 941	259	371 304	348			335 480	503
Milled rice	47 480	374	837 920	548	320 143	629	282 315	356			1 885 334	438	19 085	688	77 202	387	11 444	484		
Maize			16 636	354			229 596	301	15 395	669			103 921	243			5 704	436	173 824	329
Sorghum													437 117	218					30 065	463
Soybean							15 778	305	18 68	1 006									20 818	459
Dry bean					40 284	291	26 096	586					69 122	626						
Rapeseed oil	7 000	7 000																		
Soybean oil									14 167	2 350							7 459	1 197	21 937	1 360
Vegetable oil	22 500	1 218			32 292	543														
Palm oil	78 000	1 205	74 449	988	134 600	1 150	53 6572	844	5 343	1 936	780 000	1 282	62 100	900	203 096	872	60 104	906		
Sunflower oil									3 031	1 688			51 600	872					70 614	1 362
Soybean cake			15 916	502																
Sunflower cake							64 167	33												
Cottonseed cake							39 948	93											30 338	272

Source: FAO (2012a).

TABLE 9

Export of major food/feed commodities from the ten selected sub-Saharan Africa countries in 2010 (quantity in tonnes and price in US$/tonne)

Ingredient	Congo, DR		Côte d'Ivoire		Ghana		Kenya		Malawi		Nigeria		Sudan		Uganda		Zambia		Zimbabwe	
	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price
Sorghum							49 709	178					5 001	440						
Maize					8 720	1 346			7 841	648					127 314	214	59 584	590		
Maize flour									1 845	529					57 221	127				
Maize bran																	33 369	125		
Wheat	430	233							7 337	90			600	460			3 016	393		
Wheat bran	29 030	149	81 668	93			26 822	37	6 990	94	127 597	147	5 952	171	24 198	84	4 545	64		
Wheat flour			63 447	383					6 681	453					14 440	229	43 705	619		
Milled rice															40 009	411				
Dry bean									7 254	924					18 773	388				
Cocoa paste			147 371	4 062																
Cocoa powder/cake			30 420	3 709							8 098	2 775								
Cocoa bean	1 167	2 255	790 912	3 135	281 437	3 011					226 634	2 912			16 850	2084				
Banana	887	53	335 593	404	11 030	246							3 264	503					3 244	139
Dry pea							20 559	639	20 475	968										
Molasses													6 000	165	14 105	34	42 497	42	28 940	65
Vegetables (fresh/dried)	239	2 669					42 435	3 543			7 488	1 446	6 635	1 162						
Cassava, dried															11 397	58				
Soybean									10 671	656	11 000	345					14 445	413		
Soybean cake															62 104	59	15 066	439		
Sesame seed					7 406	444					140 800	987	138 000	1 319	12 071	1 065				
Sunflower seed									6 681	547										
Sunflower cake															20 223	33				
Cottonseed			36 132	189					7 256	141	8 600	366					32 603	162	12 844	252
Cottonseed cake																	14 968	184	30 296	271
Palm kernel cake											65 500	153								
Palm oil	500	350	201 172	750	55 000	836	69 790	1 198			13 000	923			19 755	853				
Palm kernel oil	800	1 500									3 000	1 000								
Vegetable oil					5292	1 336														
Sunflower oil													6 000	2 300						

Source: FAO (2012a).

The composition of feed ingredients that can be used for tilapia feed formulation in some SSA countries is given in Table 10. The nutrient contents of these feedstuffs vary significantly from one country to another, depending on their quality, processing and storage. For example, the protein content of sunflower cake ranges from 26 percent (Kenya) to 42 percent (Uganda). Similarly, the lipid and ash contents of sunflower cake range from 4.4 to 14.3 percent and from 5.1 to 32.6 percent, respectively.

TABLE 10

Proximate composition of selected feedstuffs for production of Nile tilapia (*Oreochromis niloticus*) in selected sub-Saharan African countries

Product	DM	CP	CL	CF	NFE	Ash
Animal sources						
Freshwater shrimp meal[1]	87.7	63.5	1.3	5.0	6.7	22.8
Fishmeal[2]	87.0	47.3	21.9	0.8	0.1	26.9
Meat and bone meal[2]	98.7	55.6	25.3	0.1	-	14.7
Blood meal[3]	87.6	60.5	2.3	0.0	11.7	25.5
Hydrolysed feather meal[1]	89.1	79.7	2.4	4.8	9.6	3.5
Hydrolysed feather meal[1]	89.7	80.8	1.9	3.1	4.3	10.0
Omena (*Rastrineobola argentea*)[1]	87.9	55.1	18.7	1.3	6.8	18.2
Seed meals						
Cottonseed cake[1]	89.3	38.8	10.7	24.9	19.2	6.3
Cottonseed cake[1]	90.2	39.3	8.1	48.5	21.7	30.1
Cottonseed cake[3]	94.0	41.1	6.2	6.2	38.0	7.9
Soybean cake[3]	87.0	43.0	1.8	6.5	-	-
Papaya seed meal[1]	94.5	26.4	31.6	11.9	20.3	9.8
Sesame cake[3]	89.5	38.5	9.0	4.0	-	-
Sunflower seed cake[1]	92.9	25.9	5.4	36.8	26.6	5.1
Sunflower cake[3]	91.0	34.1	14.3	6.6	13.2	31.8
Sunflower cake[1]	93.1	25.9	4.4	4.4	34.5	32.6
Sunflower oil cake[3]	94.8	41.7	12.9	16.5	30.8	4.6
Soybean[2]	94.2	52.9	1.4	4.0	35.0	6.7
Sunflower cake[2]	98.5	25.3	15.3	22.9	31.2	5.3
Cereals						
Maize[4]	90.2	13.2	11.4	4.8	65.4	5.2
Cassava[3]	88.0	2.5	-	4.5	-	-
Millet[5]	91.3	4.8	1.3	38.3	41.2	5.7
Sorghum[5]	88.0	7.8	4.8	7.6	65.7	2.1
Cereal brans						
Maize bran[1]	89.4	11.8	10.7	5.5	69.1	2.9
Maize bran[6]	89.0	11.6	4.4	12.3	57.7	3.0
Maize bran[2]	92.0	10.1	9.6	14.7	54.5	11.0
Rice bran[1]	92.3	7.0	4.1	30.9	34.9	22.9
Rice bran[6]	92.1	6.4	6.9	42.3	15.1	22.0
Wheat bran[1]	88.2	17.1	5.8	12.7	58.2	6.0
Wheat bran[6]	88.3	14.3	6.5	31.5	19.0	13.8
Wheat bran[2]	87.7	13.8	10.8	9.1	52.9	1.1
Groundnut bran[7]	94.0	21.7	9.0	17.5	47.0	4.8
Plant parts						
Arrowroot leaves[1]	90.3	33.5	8.5	10.6	38.1	9.3
Banana peel[1]	90.1	7.2	7.9	11.3	62.7	10.9
Banana stem[1]	92.6	10.0	5.0	44.1	20.5	20.5
Banana leaves[1]	89.9	17.0	12.7	24.1	33.7	12.4
Boiled tea leaves residue[1]	91.9	27.9	14.9	14.8	37.7	4.7
Cassava leaves[1]	91.9	30.8	8.6	15.6	36.8	8.2
Leucaena leaves[1]	92.9	28.0	7.1	15.8	39.1	9.9
Mango seed embryo[1]	90.7	7.0	9.7	3.7	77.1	2.4
Papaya peel[1]	83.9	17.9	1.8	19.4	45.6	15.4
Papaya leaves[1]	90.3	28.2	10.5	13.0	32.9	15.4
Pyrethrum, whole[1]	89.0	15.0	4.5	28.2	42.0	10.4
Sweet potato leaves[1]	89.2	35.3	4.3	10.5	38.8	10.4
Water fern, whole[1]	88.8	23.2	4.9	30.2	23.9	17.9
Water hyacinth, whole[1]	89.5	13.3	1.8	26.0	40.7	18.8

Notes: DM = dry matter, CP = crude protein, CL = crude lipid, CF = crude fibre, NFE = nitrogen free extract; Some of the columns showing these analyses do not add to 100%; however, these were the data reported in the cited papers
Source: [1] Munguti *et al.* (2006) (Kenya); [2] Chimatiro and Chirwa (2007) (Malawi); [3] Rutaisire (2007) (Uganda); [4] Nalwanga *et al.* (2009) (East African countries); [5] Ayinla (2007) (Nigeria); [6] Liti *et al.* (2006b) (Kenya); [7] Abban (2005) (Ghana).

As exemplified in Table 10, substantial amounts of information are available on the proximate composition of conventional and unconventional feed ingredients that are locally available in SSA and have potential as fish-feed inputs. Several studies have been carried out on the optimal inclusion levels of these ingredients in tilapia feeds (El-Sayed, 1999, 2006; El-Sayed and Tacon, 1997). However, in SSA countries limited information is available on the replacement of expensive protein sources, especially fishmeal, with locally available animal and plant protein sources. Only a few studies have been carried out in this regard, most of them in Nigeria (Table 11). On the other hand, local protein sources (mainly oil seed cakes) and energy sources are widely used for tilapia feed formulation (Table 6), but mostly without scientific basis.

TABLE 11

Inclusion levels of different feed ingredients in tilapia feeds in the sub-Saharan Africa region

Feed source (country)	Levels tested (%)	Requirement (%)	Species (weight, g)	References
Shrimp head waste (Nigeria)	0–60	60	*Oreochromis niloticus* (1.4)	Nwanna and Daramola (2000)
Fish silage + soybean meal or meat and bone meal (Nigeria)	0–75	50–75	*O. niloticus* (8)	Fagbenro (1994)
Poultry by-product meal or hydrolysed feather meal (1:1) (Nigeria)	0–75	50–75	*O. niloticus* (8)	Fagbenro, Jauncey and Haylor (1994)
Jackbean meal (cooked in distilled water) (Nigeria)	20–30	20	*O. niloticus* (7.6)	Fagbenro, Adeparusi and Jimoh (2004)
Jackbean meal (cooked in trona[1] solution) (Nigeria)	20–30	30	*O. niloticus* (7.6)	Fagbenro, Adeparusi and Jimoh (2004)
Defatted cocoa cake (Nigeria)	100	100	*Tilapia guineensis* (52)	Fagbenro (1988)
Macadamia press cake (Nigeria)	0–100	50	*O. niloticus* (7.5–12)	Balogun and Fagbenro (1995)
Macadamia press cake (Nigeria)	100	100	*T. guineensis* (NA[2])	Fagbenro (1993)
Cottonseed meal (Kenya)	0–100	100	*O. niloticus* (45), in fertilized ponds	Liti *et al.* (2006a)

[1] Trona (sodium sesquicarbonate/trisodium hydrogendicarbonate dihydrate, $Na_3(CO_3).(HCO_3).2H_2O$) is used as a food additive in many African countries. It tenderizes foods and meat and reduces the cooking times for cowpeas. Trona also inactivates the anti-nutritional factors in jackbean seeds (Fagbenro, Adeparusi and Jimoh, 2004).
[2] NA = not available.

6. PROBLEMS AND CONSTRAINTS OF TILAPIA FEEDS AND FEEDING

In the Conference on Aquaculture in the Third Millennium, which was held in 2000 in Bangkok, Thailand, it was reported (Machena and Moehl, 2001) that:

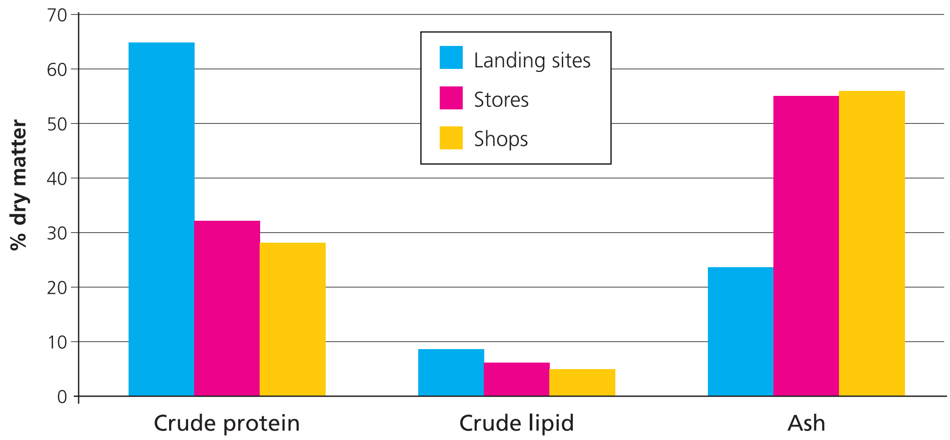
- feed is one of the major problems facing aquaculture expansion in SSA;
- the main aquafeed problems are: poor quality, little availability and the varying requirements of different species;
- farm-made feeds are dominant and are often based on the available agricultural by-products;
- little amounts of commercial feeds are produced by the private sector.
- imported pelleted feeds are not affordable by small- and medium-scale tilapia farmers, due to their high prices; and
- high transport costs and poor transport and storage infrastructure are major constraints facing the aquafeed industry in SSA.

Ten years later, the situation is still almost the same. Problems related to feed handling, transport costs, quality issues and storage infrastructure still exist. Commercial aquafeed mills are also still few because commercial production is not cost-effective and the market does not justify industrial-scale production. Therefore, organic and chemical fertilizers offer options for many small- and medium-scale farmers. Locally made aquafeeds also provide justifiable alternatives and play a significant role in aquaculture production across the region.

High transport costs, poor transport and storage infrastructure and bad feed supply chains remain key factors hampering aquaculture development in SSA. Feed and feed ingredients are often transported to remote areas where aquaculture is practiced. Transport infrastructure in many areas is poor, and some roads are not usable during the rainy seasons in many countries (Randriamiaran, Rabelahatra and Janssen, 1995; Machena and Moehl, 2001).

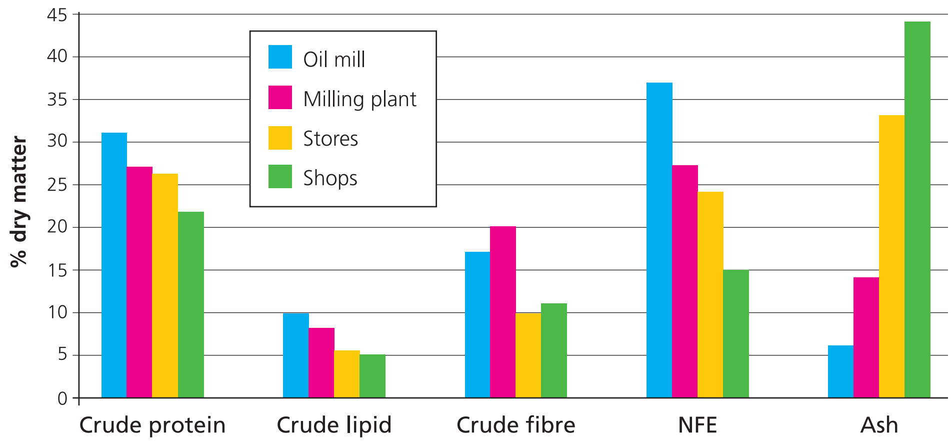
The quality of fish feed may also be subjected to sharp deterioration during storage and distribution through the supply chain. In a recent and comprehensive study, Nalwanga *et al.* (2009) investigated the nutrient content of selected feed ingredients, including fishmeal, cottonseed cake and sunflower cake at different points of the supply chain in Uganda and Kenya. These authors also compared the determined nutrient composition of commercial fish feeds with their labelled nutrient contents. The composition of those tested substantially differed from the values labelled by the manufacturers (Table 12). Market prices of feed ingredients along the supply chain had also been substantially increased. Nalwanga *et al.* (2009) also found that serious deterioration had occurred in the quality and composition of feed ingredients between the primary outlets and the stores or shops (Figures 10 and 11).

FIGURE 10
Nutritional composition of fishmeal at different points in the supply chain



Source: Redrawn from Nalwanga *et al*. (2009).

FIGURE 11
Nutritional composition of cottonseed cake at different points in the supply chain



Source: Redrawn from Nalwanga *et al*. (2009).

TABLE 12
Examples of crude protein (CP) content (%) as labelled and as analysed for fish feeds in Uganda

Type of feed	Fry pellets	Starter 1 pellets	Starter 2 pellets	Grower 1 pellets	Grower 2 pellets	Grower 3 pellets
Labelled CP	44.0	36.0	35.0	32.0	32.0	28.0
Determined CP	46.7	27.2	27.5	28.9	26.5	30.1

Source: Nalwanga *et al.* (2009).

One other major challenge facing the aquafeed industry and aquaculture development in SSA is the lack of legal and regulatory frameworks for fish feed management and the environmental effects of feed uses. No regulatory standards exist on feed composition, feed performance, feed use/quota, suspended solids, effluent treatment, enrichment, etc. In other words, none of the countries in the region have adopted any codes of conduct (COC) or best management practices (BMP). Therefore, fish feed certification is lacking in the region, and there is no assurance that fish farmers receive quality feeds.

7. RECOMMENDATIONS

In order for the aquafeed industry in SSA to be sustainable and cost-effective, the governments of countries of the SSA Region should:

- Enact legislation and regulations necessary to guarantee the proper management, quality and safety of aquafeeds. Such legislation must specify feed standards, establish basic procedures for enforcement and provide guidelines to be respected by the industry and practitioners in the production and use of aquafeeds. Legislation should also specify feed composition, manufacturing, handling, storage and use. Governments must also undertake periodic reviews of food/feed legislation to ensure their coherency and to reduce overlaps and conflicting jurisdictions.
- Promote domestic feed industries by reducing or removing taxes on imported feed milling machinery and basic feed ingredients.
- Develop country-specific farm-made feed formulations and promote research on tilapia nutrition and feed management, with emphasis on nonconventional feed ingredients.
- Promote the adoption of appropriate feed manufacturing guidelines and standards and develop appropriate low-cost machinery for milling, mixing and manufacture of feeds.
- Ensure aquafeed quality and safety through inspections and feed certification, and make information on the availability, quality and prices of processed feeds and feed materials available to producers through proper information dissemination systems.
- Improve capacity building for the aquafeed industry and provide the necessary extension services and training for fish feed technologists, including training on commercial and on-farm feed formulation, pelleting and manufacture.
- Adapt and improve low-cost feed drying technologies and develop appropriate storage facilities to prevent spoilage and maintain the quality of both feed ingredients and processed aquafeeds.
- Evaluate and test alternate feed ingredients and determine their optimal inclusion rates, improve the quality (digestibility and utilization) of these feed sources and evaluate their availability, accessibility, prices and nutritional values.
- Quantify the demand for animal manure in tilapia culture at the country level and devise low-cost distribution plans.
- Assist fish-producer organizations to participate actively in the development of the sector through information sharing among stakeholders, lobbying for collective bargaining and public-sector intervention, and linking with research organizations.

ACKNOWLEDGEMENTS

I would like to express my sincere thanks to all those who provided me with valuable information and data. Special thanks go to Drs Watson Pasipamire (Zimbabwe), Iain Gatward (United Kingdom), Nilson Agbo (Ghana), Harrison Charo-Karisa (Kenya), Rosemary Nalwanga (Kenya), Beatrice Nyandat (Kenya), Emmanuel Kaunda (Malawi) and Priscilla Longwe (Malawi). The information and photographs obtained from SARNISSA (Sustainable Aquaculture Research Networks in sub-Saharan Africa) are also highly appreciated.

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