
FUTURE TRENDS OF TILAPIA AQUACULTURE IN THE AMERICAS

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ABSTRACT

Tilapia is a relatively new seafood product in the Americas. Aquaculture of tilapia in the Americas began with small scale culture for subsistence farming in the late 1960s and 1970s. Large scale production and international trade of tilapia products developed in the 1980s and 1990s. Rapid increases in production can be attributed to improvements in aquaculture technology and infrastructure in several nations in the Americas that are major producers, and to greater numbers of trained biologists. Increases in consumption of tilapia are the result of more consumer recognition, improved quality, variety of product forms, better marketing, and overall increased demand for fish products. The Mozambique tilapia, *Oreochromis mossambicus*, was the first species widely distributed in the Americas and still accounts for a significant proportion of tilapia production. Other tilapia species, hybrids and strains have since become more popular. In the future, we can expect a decrease in the number of species farmed. However, the industry is likely to see increases in the number of strains or breeds of *O. niloticus* and red hybrid strains available. The volume of tilapia produced in the Americas is likely to double in the next 10 y. Most of these increases will occur in tropical regions. Temperate regions will see a moderate increase in production that will primarily supply niche markets for live fish and local fresh product. In both the tropics and temperate zones, production will become more intensive with more complete diets, aeration, water reuse, and disease control as important factors. Another trend that is likely to continue is increased processing in the country of origin. Levels of sophistication in production, processing, and packaging have risen considerably in recent years and this trend will continue. Several countries have adopted Hazard Analysis at Critical Control Points (HACCP) as the basis for their processing regulations, which will facilitate ex-

port of tilapia products to the US and Europe. Technology, equipment, and expertise are rapidly spreading from the US, Europe and Israel to Latin America and the Caribbean. Domestic markets outside the US and Canada are also absorbing higher value forms of tilapia. This increase in demand for filleted and packaged products has benefited producers outside the US by reducing transportation costs and smoothing out demand swings. Organization of the Tilapia Marketing Institute (TMI) should provide a further boost to demand in the US. TMI was founded in 1998 and funded (\$250,000) by several large producers and marketers. The goal of TMI is increasing awareness and demand for tilapia products.

INTRODUCTION

Global Tilapia Production

Total world landings of tilapia from capture and culture increased from 515,000 t in 1984 to 1.16 million t in 1995. Most of the increase in production is the result of aquaculture. Between 1984 and 1995, the contribution of cultured tilapia to total tilapia landings increased from 38% (198,000 t) to 57% (659,000 t). Four cichlid species or species groups (*O. niloticus*, *O. mossambicus*, *O. aureus*, and unidentified tilapias) dominated production between 1984 and 1995; in 1995, these accounted for 99.5% of cichlid production. Global production was influenced greatly by rapid expansion of *O. niloticus* culture in China, the Philippines, Thailand, Indonesia and Egypt. *O. niloticus* dominates global tilapia culture. Its share of total tilapia production increased from 33% or 66,000 t in 1984 to 72% or 474,000 t in 1995. China is now the leading producer, having increased production from 18,000 t in 1984 to 315,000 t in 1995 (FAO 1997).

North and South America

Total tilapia production in the Americas was approximately 204,267 t in 1998 (Table 1). In 1995, the proportions by volume of the main cultured species were: *Oreochromis* spp., 43%; *O. niloticus*, 37%, and *O. aureus*, 20% (FAO 1997). Tilapia production increased 13%/y from 1984–1995. Production of *O. niloticus* and red tilapia have experienced the highest growth rates throughout the Americas due to high prices in markets and the high demand for large fillets. Mexico, Brazil and Cuba are the 3 largest producers (Figure 1). Some important examples of intensive culture are those in Jamaica (4,200 t in 1998) and Costa Rica (6,072 t in 1998). Mexico is the biggest consumer of tilapia at 94,000 t. The US is the second biggest consumer with total demand of 51,200 t in 1998. Imports of tilapia have increased rapidly since 1992 (Figure 2). Tilapia imports in 1998 were 27,820 t, which represented a live weight equivalent (LWE) of 43,000 t (Table 2) and domestic production was approximately 8,200 t. The majority of tilapia fillet products exported to the US originated in Central America and the Caribbean. In 1998, import values of fillets were \$29 million compared to \$23.7 million for whole frozen tilapia (Figure 3).

Argentina

Northern Argentina is a subtropical area that supports tilapia production, centered in the province of Formosa. Production was estimated to be 10 t in 1996–1997 (Luchini 1998; Wicki and Gromenida 1997). The primary species farmed is *O. niloticus*. The primary market for tilapia is the city of Clorinda, where it is sold either as whole fish or as fillets. In 1997, whole fish sold for US\$1.50/kg and fillets for \$6.00/kg.

Argentina	<i>O. niloticus</i>
# of Farms	Few
Production (t)	10
Consumption (t)	10
New investment	Unknown

Domestic demand and production will increase slowly. No significant exports are anticipated.

Belize

Belize has had several farms producing tilapia since the early 1990s. Imports to the US have de-

Table 1. Major producers of tilapia in the Americas. Higher than reported by Fonticella and Sonesten, This vol.

Country	Tilapia	
	Production (t)	Year
Argentina	10	1997
Belize	147	1996
Brazil	30,000	1997
Canada	100	1998
Chile	0	1998
Colombia	18,000	1998
Costa Rica	6,072	1998
Cuba	35,000 ¹	1998
Ecuador	2,318	1997
El Salvador	20	1992
Guatemala	260	1992
Honduras	3,000	1998
Jamaica	4,200	1998
Mexico	94,279	1996
Nicaragua	352	1997
Panama	65	1998
Paraguay	60	1998
Peru	0	1998
Suriname	100	1998
Trinidad	28	1998
U S	8,200	1998
Venezuela	1,936	1997
Other Nations	120	mixed
TOTAL	204,267	1998

creased from 147 t (LWE) in 1996 to 111 t in 1997, and were 0 t in 1998. It is not clear whether the decrease represents tilapia that are now being consumed domestically within Belize, or if farms have reduced production.

Belize has excellent water resources and a steady level of interest from outside investors. Production should increase moderately with much of the increase exported to the US.

Brazil

Brazil has one of the fastest growing tilapia industries in the Americas. Most of Brazil has environmental conditions conducive to tilapia culture combined with vast water resources. Tilapia were introduced to Brazil in the 1950's and were distributed widely. Demand for tilapia was slow developing, probably because of the plentiful supplies of native freshwater and marine fishes. The greatest current market for tilapia in Brazil is for stocking of fee-fishing operations in the populous regions of the southeast. This appears to be the first large scale

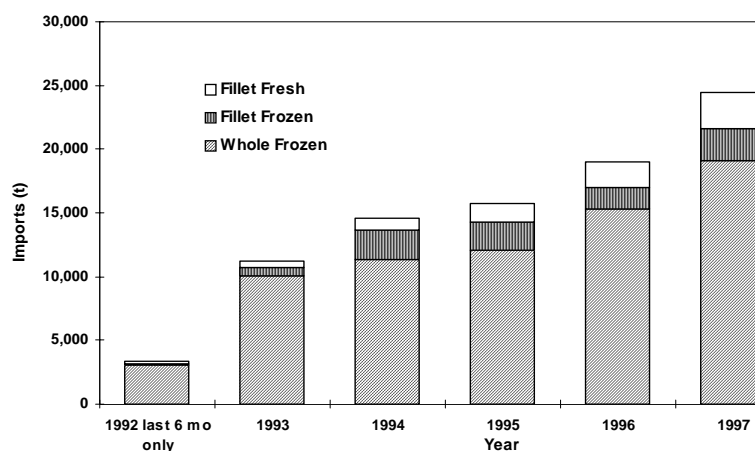
Figure 1. Tilapia production in the Americas. Size of fish symbols indicates relative size of total production.



sport fishing of tilapia. The market is supplied mostly with red tilapia. There is a growing perception of tilapia as a high quality fish. In taste tests of tilapia with native freshwater fish, a group of chefs rated tilapia the highest quality (Chammas 1999). Rapidly increasing population, along with declining yields from capture fisheries is contributing to increasing demand for tilapia products.

In the northeast region, fertilized ponds are the most common culture method. In the south and southeast regions, cages, raceways, and intensive round tanks are more common. Several large cage projects have begun since recent changes in regulations, which permit aquaculture leases in public reservoirs (Kubtiza 1999). Sex reversal is widely used, and many hatcheries advertise fingerlings in the

Figure 2. US tilapia imports (t)



Brazilian aquaculture trade journals. Brazil has also developed a leather trade based on tilapia skins. Belts, purses, wallets, and briefcases are the most popular items produced from the skins. Virtually all tilapia produced in Brazil are consumed domestically. Exports to the US fell from 1.2 t in 1997 to 0 t in 1998.

Additional rapid expansion of the industry is expected. With the devaluation of the real in early 1999, exports to the US are likely to increase. Modern processing plants currently provide high quality product to the domestic markets that could meet HACCP guidelines for the US market.

Brazil	<i>O. niloticus</i> , Red Strains	
# of Farms	N/A	
Production (t)	25,000 (aquaculture)	5,000 (wild catch)
Consumption (t)	30,000	
New investment	Yes	

Production will increase rapidly. Domestic demand will not increase as quickly. Brazil will begin exports to countries in the region and to the US. International demand for tilapia skin products will provide an extra stimulus to the industry.

Canada

Canada is one of the most interesting locations for tilapia production, and in the late 1990s has become a focus of new production and marketing. Toronto is widely recognized to be the single largest market for live tilapia in North America. The mar-

ket for live tilapia exceeded 500 t in 1998. Several of the ethnic communities in Toronto, especially the Chinese, compose a lucrative market for producers in the eastern US and Canada. A well developed distribution system with live sales that appeal to several market segments has been organized for Toronto. Most of the supply of live tilapia comes from closed recirculating systems in the US, but several producers in Canada have begun to contribute significant amounts to the market. Approval for commercial production of tilapia in Ontario was granted in 1995. Canadian growers are utilizing their expertise in greenhouse operations to operate closed recirculating systems that are producing fish that can compete with US product. Several of the producers have worked with the tilapia culture system developed by the research team at Cornell University, while others have pioneered their own systems. One of the farms was able to acquire a pure line of *O. niloticus* directly from Lake Nasser in Egypt and are using fry from these breeders to stock their facilities. These growers expect to market fry to other farms. Five farms are located in Ontario province, a 6th in Calgary and a 7th has been licensed in British Columbia. Several of the farms in Ontario are in the process of expanding and production is expected to double to 200 t within the next 2 y. The intent is to provide a ready supply to the Toronto market. Production from the existing farms has already driven down the prices paid to US producers as they must compete with farms within a short drive of the Toronto markets. The Alberta provincial government has recently organized a division of aquaculture and is encouraging fish farming in Calgary and the rest of the province. The British Columbia farm expects to compete in the Vancouver market (estimated at 5

Table 2. Tilapia imports to the United States during 1998, by product form and country of origin (Derived from NMFS, Fisheries Statistics 1999)

Country	Product Form	Kg	US\$
Canada	Fillet, frozen	34,836	156,149
Chile	Fillet, fresh	1,868	9,822
China	Fillet, frozen	38,102	217,510
	Frozen	435,259	437,364
	Total	473,361	654,874
Costa Rica	Fillet, fresh	2,206,290	10,265,503
	Frozen	3,362	5,579
	Total	2,209,652	10,271,082
Ecuador	Fillet, fresh	645,851	2,512,811
	Fillet, frozen	79,752	274,212
	Frozen	31,245	90,716
	Total	756,848	2,877,739
Honduras	Fillet, fresh	435,597	2,501,822
	Fillet, frozen	46,525	259,439
	Frozen	24,058	132,566
	Total	506,180	2,893,827
India	Fillet, fresh	21,760	34,778
Indonesia	Fillet, frozen	885,296	4,258,091
Jamaica	Fillet, fresh	181,984	1,212,093
	Fillet, frozen	99,268	356,876
	Total	281,252	1,568,969
Malaysia	Frozen	9,645	9,548
Mexico	Fillet, fresh	1,057	6,626
Nicaragua	Fillet, fresh	6,587	40,398
	Fillet, frozen	21,914	94,786
	Frozen	318	1,875
	Total	28,819	137,059
Panama	Fillet, fresh	3,845	18,179
Philippines	Fillet, frozen	18,457	21,705
Taiwan	Fillet, fresh	84,863	449,110
	Fillet, frozen	1,334,407	5,447,635
	Frozen	20,995,322	23,002,925
	Total	22,414,592	28,899,670
Thailand	Fillet, frozen	137,669	873,409
	Frozen	35,235	48,489
	Total	172,904	921,898
Total US Imports	Fillet, fresh and frozen	6,285,928	29,016,954
	Frozen, round	21,534,444	23,729,062
	All forms	27,820,372	52,746,016

t/wk) now supplied by farms in Idaho and North Dakota (Morris 1999).

Canada is also an important importer of fresh and frozen tilapia products from producers in Jamaica and Costa Rica. Fillet products are reported to be common in markets and restaurants. With continued short-

ages of domestically caught fish, tilapia is likely to increase its market share further in Canada.

Canada	<i>O. niloticus</i>
# of Farms	6-8
Production (t)	100
Consumption (t)	500+
New investment	3 farms

Production is expected to increase quickly to 300% of the current level. Demand for live and fresh product will increase steadily, and Vancouver will become an important market. Demand for fillet product from off shore suppliers will increase steadily. Canada will be another center of technology development of recirculation systems.

Chile

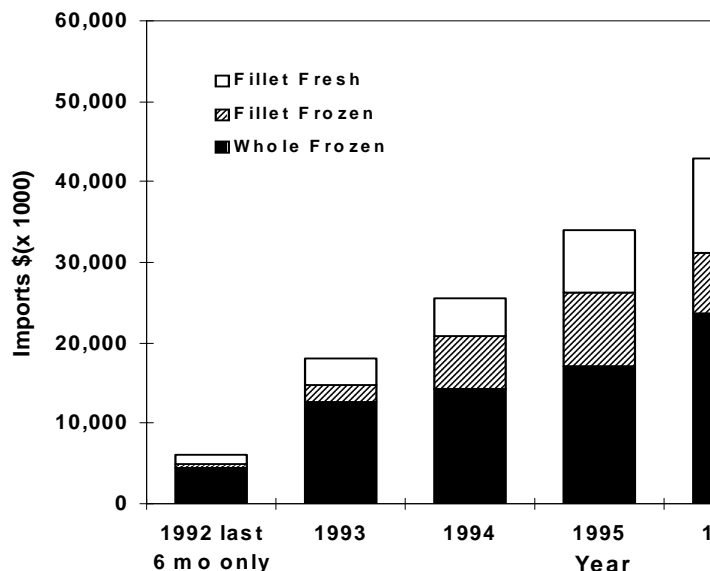
Chile has a well developed aquaculture industry for salmon. In 1998, the US reported 1.3 t of fresh tilapia fillets imported from Chile. However, there are no reports of tilapia production in Chile. Imported tilapia were likely trans-shipped through Chile and were actually produced in a neighboring country. There is not likely to be much tilapia production in Chile and local demand is expected to be minimal.

Colombia

Tilapia were introduced to Colombia in 1960. Small scale aquaculture spread through the country, supported by international aid agencies and the Colombian government. Large scale commercial production began in the late 1980s. Several farms were built using intensive pond production techniques with rapid water exchange. These farms were stocked with red tilapia strains, and fish were processed for export to the US. Production volume increased rapidly between 1994 and 1998 from 8,000 t–18,000 t (Sepúlveda Cárdenas 2000).

The majority of tilapia produced have been red tilapia strains. In recent years *O. niloticus* has become more common. In the early 1990s most tilapia were exported as frozen fillets to the US. In the mid-1990s a domestic market grew that accepted the fish in fresh forms (whole and fillet) and reduced export levels. US imports of Colombian tilapia were 224 t of fillets in 1996, 5 t in 1997, and 0 t in 1998. Colombia now imports tilapia from Venezuela to supply domestic demand.

Figure 3. Declared value of US tilapia imports.



Most commercial production comes from intensive or semi-intensive ponds. New farms are being built; existing farms are increasing production.

Colombia	Red Strains, <i>O. niloticus</i>
# of Farms	N/A
Production (t)	18,000
Consumption (t)	19,000
New investment	Yes

Domestic markets may be nearly saturated and exports to the US are likely to return to earlier levels. Value addition from breaching of fillets or other packaging is likely. Additional production is still being constructed and several farms will increase yield from existing facilities.

Costa Rica

O. mossambicus and then *O. aureus* were introduced to Costa Rica in the 1960s (Pullin et al. 1997). Small scale rural production was practiced for several years. One of the earliest attempts to introduce tilapia into international trade was a canned tilapia product developed in Costa Rica. "Lomas de Tilapia" were on the market in the early 1980s. In 1979, *O. niloticus* were introduced to Costa Rica. Taiwanese technology for intensive culture of tilapia in flow-through ponds was developed. A farm in Cañas is based on this technique and is now the single larg-

est tilapia farm in the Americas. AquaCorporacion Internacional, S. A. (ACI), the farm management company, is increasing production which was 450 t/mo in 1998.

Costa Rica	<i>O. niloticus</i> , <i>O. aureus</i> , Red Strains
# of Farms	6 major, numerous small
Production (t)	6,072
Consumption (t)	1,000
New investment	Yes

Both domestic and US markets for tilapia are growing. ACI is expanding and several new farms are in operation or in the planning stages. In addition to intensive pond operations, semi-intensive farms will make contributions. Technologies may not be developed in Costa Rica, but its farms are likely to be among the first to apply new techniques on a large scale. The same can be predicted for processing.

Cuba

O. niloticus, *O. aureus*, and *O. mossambicus* were introduced in the late 1960s. They were stocked into several reservoirs around the country. Fish migrated up and downstream from these reservoirs and now can be found from headwaters to coastal lagoons. *O. aureus* is the primary tilapia captured in reservoir fisheries, produced in hatcheries, and

grown out in ponds and cages. Reservoir fisheries are the primary source of tilapia (see Fonticiella and Sonesten, This vol.).

Cuba	<i>O. niloticus</i>
# of Farms	N/A
Production (t)	35,000
Consumption (t)	35,000
New investment	Limited

As soon as the US removes trade restrictions, Cuban tilapia will come to US markets. Cuba will be an ideal production location. Resources include a group of skilled biologists with training in biotechnology and tilapia genetics, low costs, proximity to US, proper climate and a supply of capital ready to be invested from Cuban-Americans. For the present, production will remain steady or increase slightly. In the future, the reservoir fisheries are likely to be replaced by intensive cage culture operations.

Ecuador

In Ecuador, tilapia production has been closely aligned with the marine shrimp industry. When Taura syndrome struck the shrimp industry, many producers turned to tilapia as an alternative crop. Even though tilapia was a lower value product, large quantities were grown in existing shrimp ponds. Infrastructure was readily available to process, package and transport tilapia to US markets. Exports of fresh fillets have also been seen in fish markets in Denmark (Bertel Thomsen, pers. comm.).

Some growers believe a crop rotation of shrimp and tilapia reduces shrimp diseases. Production grew quickly from 18 t in 1990 to 2,318 t in 1997. ENACA, a large shrimp farming company, is also the largest tilapia producer in Ecuador. Growth is expected to slow as many shrimp farms have already adopted the rotation scheme or have completely switched to tilapia. However, the 1999 devaluation of the sucre will provide impetus to develop tilapia further as a seafood export in addition to shrimp.

Ecuador	Red Strains, <i>O. niloticus</i>
# of Farms	100+
Production (t)	2,318
Consumption (t)	N/A
New investment	Yes

Devastation of the shrimp industry from white spot disease has provided impetus for many shrimp farms to stock tilapia, either as a crop rotation or a complete switch. Domestic demand will not increase significantly. Improvements in marine fish culture methods may find a more valuable alternative to tilapia in shrimp ponds. Roderick (1999) predicts Ecuador production will reach 9,000 t for 1999.

El Salvador

El Salvador has small farm production for local markets. During the 1980s, the University of Arizona and FUSADES, a local trade group, reviewed options for large scale farms. FUSADES has continued these efforts, but no large farms have been built.

El Salvador	<i>O. niloticus</i> , Red Strains
# of Farms	N/A
Production (t)	20
Consumption (t)	N/A
New investment	N/A

Small scale production will continue. Large farms may be built considering El Salvador's long tradition as an agribusiness center for Central America.

Guatemala

Production has been primarily small farmers for home or domestic markets. A few shrimp farms have diversified with tilapia production in some of their ponds. Production was reported to be 260 t in 1992.

Guatemala	<i>O. niloticus</i> , Red Strains
# of Farms	40+ small
Production (t)	260
Consumption (t)	N/A
New investment	?

Honduras

Extensive production of tilapia for subsistence farmers was introduced in the 1960s and 1970s. Most of this early production utilized *O. mossambicus*. Red hybrids and *O. niloticus* were introduced in the 1980s and have effectively replaced *O. mossambicus*.

at most farms. Commercial production for export began in 1989 in the Sula Valley (Teichert-Coddington and Green 1997). The original farm, and several which followed in the early 1990s, were based on Jamaican production systems utilizing intensive pond culture with paddlewheel aeration and daily water exchange. The farms also used red hybrid broodstocks imported from Jamaica. By 1997, exports to the US from these farms were 212 t (mostly fresh fillets), worth \$884,458.

In 1997, Aqua Corporacion de Honduras near San Pedro Sula began production. This farm uses technology developed by Aquaculture Production Technology of Israel including an intensive pond system rearing all male hybrid populations. The farm currently produces 1,800 t/y. Hatchery, growout and processing are vertically integrated. Fish are exported as fresh product and marketed under the "Mountain Stream" brand. New production has increased exports to the US to 506 t (mostly fresh fillets), worth \$2,893,827 in 1998 (National Marine Fisheries Service 1999). Regal Springs began operation of 2 large cage farms in reservoirs in 1999. When fully operational, these 2 farms will produce 4,000 t/y (M. Picchietti, pers. comm.; Redmayne 2000).

Honduras	Red Strains, <i>O. niloticus</i>
# of Farms	50+
Production (t)	3,000
Consumption (t)	N/A
New investment	Some

Hurricane Mitch in 1998 devastated much of the country. Several farms lost fish stocks but little permanent damage was done. By 2000 production is expected to surpass pre-hurricane levels (estimated at 5 t/wk) and continue expanding. Some farms will increase production by adding paddlewheels and switch from red tilapia to *O. niloticus*. There are plans for at least one significant cage farm operation. Honduras will join Costa Rica as the 2 major exporters from Central America.

Jamaica

O. mossambicus were introduced into Jamaica in 1949. In 1979, Auburn University, working with the Jamaican government, began working on a multi-year project to develop tilapia aquaculture across the country. Hatcheries and demonstration farms were constructed and biologists were trained. Many small farms were started and domestic consumption increased.

Eventually, large commercial producers entered the industry and developed export quality products. "Aquaculture Jamaica Limited" is the largest producer with 2 major farm sites, a hatchery, a processing plant. The company exports to the US and UK. Several producers across the country act as contract growers for Aquaculture Jamaica, primarily growing red strains and *O. niloticus* (see Hanley, This vol.).

Jamaica	Red Strains, <i>O. niloticus</i>
# of Farms	55
Production (t)	4,200
Consumption (t)	2,900
New investment	Some

There is little investment in new farms, but existing operations are improving yields and increasing intensity.

Mexico

Mexico produces more tilapia than any other country in the Americas, 94,279 t in 1996. Tilapia are cultured using extensive and intensive methods and are captured from reservoirs stocked with fingerlings. There are highly developed internal markets and few fish are exported. Culture methods have become more intensive in recent years, with improved feeds, more cage and raceway culture, genetic manipulations, and more skilled producers. The government of Mexico has begun a project to develop 3 tilapia "parks". These parks will be research, education, and demonstration sites as well as major production locations. As additional technology is applied, Mexico's tilapia production will expand rapidly. Mexico, with its large domestic demand, proximity to US markets, and enormous water resources for tilapia culture, will soon be a major factor in the international trade in tilapia (see Fitzsimmons, This vol.).

Mexico	<i>O. aureus</i> , <i>O. niloticus</i> , Red Strains
# of Farms	> 1,000
Production (t)	94,279
Consumption (t)	94,000
New investment	Yes, cages, ponds, tilapia parks

Mexico will continue to be the largest producer and consumer of tilapia in the Americas. Greater intensification and replacement of stocking and capture with cage culture, will greatly increase production. Mexico will develop an export trade to the US.

Nicaragua

Lake Nicaragua supports a significant tilapia fishery that supplies local and export markets. A number of small farms also supply local markets. Large scale farms are likely to be built in the southwest part of the country near the Costa Rican border.

Nicaragua	<i>O. niloticus</i> , Red Strains
# of Farms	N/A
Production (t)	352
Consumption (t)	N/A
New investment	Yes, cages, ponds

Nicaragua is likely to become an important producer of tilapia from intensive pond farms and from cages placed in lakes and reservoirs. Low labor costs and abundant water supplies provide excellent opportunities for growth.

Panama

Panama has had small farms for many years. Two large scale intensive pond farms are in planning stages. Panama is likely to become a significant exporter because it has excellent transportation and other infrastructure facilities.

Panama	<i>O. niloticus</i> , <i>O. aureus</i>
# of Farms	N/A
Production (t)	65
Consumption (t)	N/A
New investment	Yes, ponds

Paraguay

Tilapia were introduced in the 1960s and populations were established in the watershed of the Rio Plata. A fish farming cooperative has been organized to produce tilapia for domestic markets. The cooperative supplies 5 t/mo and has processing capabilities (Frank Fragano, pers. comm.). Additional production capacity is being developed and they hope to market frozen fillets to US markets.

Paraguay	N/A
# of Farms	N/A
Production (t)	60
Consumption (t)	60
New investment	Yes

A slight increase in domestic consumption will occur and exports to US and Brazil will develop.

Peru

Peru is unique in the Americas regarding tilapia. Tilapia production has decreased since the early 1990s. Many regions of the country are ideal for tilapia production, which peaked in 1992 with 250 t. By 1996 production had decreased to 47 t and today there is little commercial cultivation. The agriculture ministry of Peru has decided to concentrate on the aquaculture potential of native species. Aquaculture of tilapia, an exotic, has been discouraged. Tilapia production is not allowed in the Amazon Basin and no permits are issued for production in reservoirs throughout the rest of the country. Pond culture is allowed only for all male populations. Production in the early 1990s was in ponds and cages. Experimental production was conducted in integrated systems with ducks, cattle, and pigs as well as in rice culture. *O. niloticus* and red strains were reared. In 1999, the government announced that the demonstration farm facilities would be auctioned to the private sector. A separate research program was conducted in Lima. Tilapia production in treated municipal effluents was evaluated with the intent to determine if any potential human pathogens, that might be transmitted by fish to humans, were present in water after secondary treatment.

Aquaculture of endemic species will develop and tilapia production will be restricted to the coastal plain. Some production may develop in the shrimp growing region.

Suriname

Suriname has extensive water resources and great potential for tilapia production. *O. mossambicus* were first introduced for aquaculture in 1955 by the Fisheries Department. Commercial aquaculture did not develop at that time, but tilapia were stocked into natural water bodies. A small commercial fishery has developed harvesting these fish (Ouboter and Moll 1993). There are 2 small farms in operation and a large farm in the start-up stage. COMFISH is a 4 ha farm on the Commewijne River in close proximity to the capitol of Paramaribo. COMFISH uses the ND30 strain, developed by APT in Israel, in an intensive operation with anticipated production of 100 t/y (T. Frese, pers. comm. <http://www.fishfarming.com/>). The farm sex reverses fry before stocking into earthen nursery ponds. Growout is in 0.1 ha concrete tanks, stocked at 17 juveniles/

m³, with 100% daily water exchange. Automatic feed blowers are used in all tanks.

Suriname	ND30 Strain, Red Strains
# of Farms	3
Production (t)	100
Consumption (t)	1
New investment	Yes

A small domestic market will develop, but most production will go to the US as fillet product. COMFISH is expected to increase production.

Trinidad and Tobago

O. mossambicus were first imported to Trinidad in the 1940s and 1950s but were never accepted by the populace. Red strains were imported from Jamaica in 1983; *O. niloticus* were imported in 1986. These varieties were accepted by consumers and producers alike. The islands have 562 small scale (subsistence) farmers operating 706 ponds, with a total pond area of 71.6 ha. Average pond size is 0.07 ha. The government operates a commercial farm through Caroni Limited. This farm includes a hatchery and 9.5 ha of tanks and ponds (Ramnarine and Ramnarine 1997). Approximately 16 t of tilapia were produced in 1995, over 18 t in 1996, 22 t in 1997, and for 1998 the estimate is 28 t. Tilapia is presently sold at TT\$13/kg. (US\$1.00 = TT\$6.30). The major portion of the tilapia produced is consumed locally, with only a small percentage now being exported to North America and Europe (see Ramnarine, This vol.). Red tilapia strains are the most commonly reared, along with small amounts of *O. niloticus* and *O. mossambicus*. Many of the farms produce tilapia in polyculture with "cascadu" (the armoured catfish, *Haplosternum littorale*) (A. Potts, pers. comm.).

Trinidad & Tobago	Red Strains, <i>O. niloticus</i> , <i>O. mossambicus</i>
# of Farms	562
Production (t)	28
Consumption (t)	~26
New investment	Some

Consumption and production will slowly increase. Some farms will adopt more intensive production techniques.

United States

Tilapias were first introduced into the United States in the 1950s and 1960s. These early introductions were conducted by public aquaria for display purposes and by government agencies interested in the potential of tilapia for use in food production and as biological controls for aquatic weeds and insects. Tilapia were also introduced into the Hawaiian Islands as a potential baitfish for the tuna industry.

Tilapia aquaculture has grown from early efforts which concentrated on supplying the fish to irrigation districts and natural resource agencies for weed control to development of domesticated strains that are used almost exclusively for production of fish for direct human consumption. Tilapia have fallen out of favor as biological control agents for weeds in North America because of the greater control that can be achieved with the triploid grass carp.

Most production in the US occurs in recirculating systems that use greenhouses or industrial waste heat to maintain optimum growing conditions. In Arizona, California, and Idaho, geothermal waters are used. In the southeastern US pond culture is possible (see Hargeaves, This vol.). Most US producers sell to niche markets concentrating on live sales and ethnic restaurants. New markets are developing as processors have developed value-added products (marinated, breaded and microwave ready) that are gaining market share (Table 3).

United States	<i>O. aureus</i> , <i>O. niloticus</i> , Red Strains
# of Farms	200+
Production (t)	8,200
Consumption (t)	51,200
New investment	Yes, recirculating systems

The US will continue to be a major market for tilapia products from other countries. Domestic production will increase steadily as niche markets widen and value-added product forms gain acceptance. The US will continue to be a technology center for the entire region, developing recirculation techniques that will be adapted to hatcheries and growout facilities.

Venezuela

O. mossambicus were first introduced from Trinidad in 1959. Commercial tilapia production was

Table 3. Typical prices for tilapia products sold in the US as of September 1999 (from personal communications and advertisements).

	Pond-Side/Processor \$/kg	Wholesale \$/kg	Retail \$/kg
Whole live fish	2.20-6.60	2.80-7.50	4.00-10.00
Whole frozen fish	1.10-2.00	2.00-2.35	2.20-5.00
Whole fresh fish	2.30-3.00	3.00-4.00	4.00-9.00
Fillets, fresh	5.00-7.00	6.00-8.00	8.00-12.00
Fillets, frozen	4.80-6.75	5.50-7.80	7.00-11.50

approved by the government in 1992. Most production has developed in the states of Tachira, Barinas, and around Lago de Maracibo. There were 152 farms licensed to produce tilapia in 1997, with 133 ha in production, 95% in semi-intensive pond production, 5% in intensive concrete tank culture (G. Conroy, pers. comm.). Red tilapia, introduced from the US, Jamaica and Israel (Polanco 1998) and *O. niloticus* are most commonly reared. Many tilapia farms are integrated into existing small farm operations with one or 2 small ponds while others are integrated into larger ranching operations with multiple ponds and more sophisticated operations. Some of these farms have further diversified to also produce “cachama” (*Colossoma macropomum*) (M. Martinez, pers. comm.). Most of the tilapia produced are consumed in Venezuela and sold in the round, or gutted on ice. Tilapia are exported to Colombia, France, and the US, and require additional processing. Additional production is planned, and will be aimed at US markets. Servicio Autonomo de los Recursos Pesqueros y Acuicolas (SARPA) of the Ministry of Agriculture is the agency that regulates and supports aquaculture development. SARPA has restrictions on introduction of tilapia to natural bodies of water, but expects tilapia production in private production facilities to continue to increase rapidly into the next decade (Capecchi 1997).

Venezuela	Red strains, <i>O. niloticus</i>
# of Farms	152
Production (t)	1,936
Consumption (t)	1,700
New investment	Some

Production will increase steadily. Jory et al. (1999) report that there may be 200 farms in operation. Domestic demand will increase slightly, but new production will be directed to US fillet markets (Alceste and Jory 1998). Improvements in fry availability and feed quality should further boost pro-

duction. Polyculture with *cachama* will be adopted on many farms.

FUTURE PERSPECTIVES

The countries of the Americas are relatively small markets and producers compared to China and other Asian countries. However, the US is a rapidly growing market that has encouraged tilapia farms to develop throughout the Americas. In 1986, essentially all US demand was met by domestic producers. By 1998, a vastly increased US market was comprised of 80% imports. In 1998 the US imported 43,000 t of LWE tilapia compared to 8,200 t of domestic production (American Tilapia Association 1999). Prices for tilapia products vary considerably across the US. Live fish sold by the producer will range from \$2.20–\$6.60/kg at the farm. Prices for processed forms vary considerably.

Growth of domestic markets in South and Central America has further supported demand. In some countries domestic demand has absorbed local production and exports to the US have declined. This diversification is beneficial to the producers since the local markets reduce shipping and processing costs. Producers can also take advantage of seasonal peaks in US demand (Lent and summer). Mexico and Brazil in particular have strong domestic markets. These 2 countries with large populations and enormous aquatic resources will be the 2 major players in the Western Hemisphere tilapia industry. Tilapia markets throughout the Americas will diversify as more value-added products are offered. Breaded, marinated, and microwave ready tilapia will be processed and marketed throughout the region.

US producers are increasingly dependent on recirculating systems, even in areas with access to warm water supplies. Concerns over effluent discharges are helping to drive this trend. Hatcheries in Central and South American countries are also

likely to incorporate recirculating systems and nurseries in an effort to improve water quality, productivity and broodstock management.

Tilapia aquaculture in the Americas has a bright future and will continue to see rapid growth. There will be impressive successes and spectacular failures as additional participants join the industry. Markets will increase steadily and production will follow in fits and starts.

CONCLUSIONS

- By 2010, total production in the Americas will increase to 500,000 t/y (Table 4);
- Sex-reversed *O. niloticus* will account for the majority of tilapia production;
- Genetically male tilapia and all-male hybrids will provide a majority of fingerlings;
- *O. aureus* and *O. mossambicus* will be used only to create hybrids;
- Red strains will account for 20–30% of all tilapia produced;
- Most tilapia fingerlings will come from intensive hatchery/nursery operations;
- Intensive ponds will provide 50% of production;
- Large scale cage operations will provide 20–30% of production;
- Indoor recirculating systems will provide 10% of production;
- Nutrition will improve with FCR's approaching 1.0;
- Mexico and Brazil will be the major producers and major consumers;
- US will be the 3rd largest producer, 3rd largest consumer, and the largest importer;
- Production will be more intensive in every country;
- More processing will occur in countries of origin;

Table 4. Estimated tilapia production, 1999–2010

Country	Estimated Tilapia Production		
	1999 t	2000 t	2010 t
Argentina	12	14	46
Belize	150	180	400
Brazil	35,000	40,000	125,000
Canada	140	200	700
Chile	0	0	0
Colombia	20,000	21,000	48,000
Costa Rica	7,000	7,500	21,000
Cuba	36,000	39,000	55,000
Ecuador	5,000	8,000	20,000
El Salvador	20	30	90
Guatemala	260	260	800
Honduras	4,000	5,000	7,000
Jamaica	4,400	4,600	9,000
Mexico	102,000	105,000	182,000
Nicaragua	400	500	3,000
Panama	65	80	900
Paraguay	60	80	200
Peru	0	0	0
Suriname	105	200	800
Trinidad	29	30	64
USA	9,000	10,000	17,000
Venezuela	2,000	2,200	7,000
Other Nations	140	180	2,000
TOTAL	225,781	244,054	500,000

- Amount of “value adding” will increase rapidly with more fillets, breeding, marinated product will enter markets;
- 5% of tilapia will be grown in polyculture with *Macrobrachium*, red claw, *cachama* or other fish.

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