ABSTRACT

Tilapia farmers often have problems deciding if Nile tilapia or red tilapia is the proper choice for culture. Nile tilapia is the most widely farmed tilapia world-wide but interest in red tilapia culture is growing rapidly. Nile tilapia are more dependable spawners and produce more consistent quantities of fry than red tilapia. Survival of eggs, fry and juveniles is higher for Nile tilapia and Nile tilapia are more tolerant of low water temperatures than most strains of red tilapia. Red tilapia often have higher market value, are more appropriate for culture in salinities above 10 g/l, and are easier to seine harvest from earthen ponds and transport live than Nile tilapia. Red tilapia need continual selection to retain their red color and pass the red color from generation to generation. Farmers should evaluate environmental conditions, culture system and markets before selecting either Nile tilapia or red tilapia for culture.

INTRODUCTION

Tilapias are second to the carps in weight harvested from culture ponds. Lovshin (1997) estimates that over 800,000 MT of tilapia were farmed in 1996. Tilapias are native to Africa, Israel and Jordan and have been distributed round the world. The majority of farmed tilapias are produced in countries with tropical or subtropical climates. Tilapias are cultured in countries with temperate climates but must be held in warm water to survive the cold winter months outdoors. Major tilapia producing countries are found in Asia, with Mainland China (310,000 MT), Philippines (91,000 MT) and Taiwan (90,000 MT) the world's leaders (Lovshin 1997). Tilapia farming is increasing in the Americas with the growth of domestic markets and the export market to the United States. Brazil (20,000 MT), Columbia (16,057 MT), United States (8,600 MT) and Jamaica (5,000 MT) are the principal tilapia farming countries in the Americas (Lovshin 1997; 1998). The Nile tilapia, Oreochromis niloticus, is the most widely cultured tilapia in the world because of its rapid growth,
late age of sexual maturity and planktivorous feeding habits. However, the red tilapia, *Oreochromis sp.*, is increasing in popularity among producers due to its attractive color, increased marketability and high salinity tolerance in some strains. The red tilapia has replaced the Nile tilapia as the tilapia of choice among producers in Colombia (Gonzalez 1997) and Jamaica (Carberry and Hanley 1997) because of demand by domestic consumers. Red tilapia are cultured in the Philippines where the market price per kilogram is twice that of the more widely cultured Nile tilapia (Romana - Eguia and Eguia 1999). This paper will review the literature concerning the genetic background of red tilapia and compare major advantages and disadvantages of farming Nile and red tilapias.

**GENETICS**

Red tilapia are genetic mutants selected from tilapia species in the genus *Oreochromis*. *Oreochromis sp.* are taxonomically distinct from other tilapia genera because females incubate fertilized eggs in their mouths. Thus, red tilapia breed similar to Nile tilapia, Blue tilapia, *O. aureus*, Mozambique tilapia, *O. mossambicus*, and Zanzibar tilapia, *O. hornorum*. The first reported red tilapia hybrid was produced in Taiwan in the late 1960s and was a cross between a mutant reddish-orange female *O. mossambicus* and a normal male *O. niloticus* and is called the Taiwanese red tilapia (Galman and Avtalion 1983). Another red tilapia strain was developed in Florida in the 1970s by crossing a normal colored *O. hornorum* female with a red-gold male *O. mossambicus* (Behrends et al., 1982). The Florida red tilapia was introduced to Brazil and Jamaica from where it was distributed in its original genetic form or after crossing with Nile and Blue tilapias to numerous Central and South American countries. A third red tilapia strain was developed in Israel from red Nile tilapia originating from Egypt crossed with wild-type Blue tilapia (Hulata et al. 1995) and was introduced to Jamaica and Colombia. Other red tilapia strains are likely to have been developed but published information on their origins is unavailable. Unfortunately, all 3 original stains have been crossed with other red tilapia of unknown origin or with wild-type *Oreochromis sp.* so that the genetic makeup of most red tilapia is unknown. Commonly, off-spring from red tilapia parents will contain fingerlings with wild or dark coloration and red or pink coloration with irregular black spots. Some strains of red tilapia breed true, meaning that 100% or close to 100% red offspring will result when a red male is crossed with a red female. However, 100 % red coloration is a misnomer as red color is used to describe a number of color variations including white, pink, bronze, red-orange and red phenotypes and combinations of these colors on the same fish (Behrends et al., 1982; Halstrom 1984). A true breeding red tilapia will not have offspring with dark coloration or with irregular black spots mixed with red or pink. Red tilapia brood stock must be continually selected for red color or over a number of generations the off-spring will show signs of reverting to original wild coloration. However, continual selection for red color may also select for characteristics that are not beneficial in a culture fish. Continual inbreeding of tilapia for red color is suspected as the cause of poor egg, fry and fingerling survival among some red tilapia strains. The confused and rapidly changing genetic make-up of red tilapia make selection of a best strain for culture difficult.

Genetic determination of red color in tilapia is not fully understood. McAndrew *et al.* (1988) found that red color in Nile tilapia was caused by a dominant genotype while Tave *et al.* (1989) found that gold pigmentation in Mozambique tilapia was due to a recessive genotype. Huang *et al.* (1998) suggested that red body color in the *O. mossambicus x O. niloticus* Taiwanese red tilapia
was inherited as a single gene with incomplete dominance. Huang et al. wrote that RR is the genotype for pink body color, Rr for red color and rr for black color. Behrends and Smitherman (1990) suggest that red coloration in tilapia may be explained by any of three systems: one gene with co-dominance; two genes with recessive epistasis; and two genes, each with complete dominance, and each of which controls a separate phenotype. Determination of color in tilapia is complicated by the diverse genetic make-up of red tilapia hybrids and the many color variations of red that have been described and found among off-spring from a common female. Additionally, some color phenotypes are sub-viable and some phenotypes change color over time making genetic determination of color complex.

Saltwater Tolerance

Some strains of red tilapia are salt water tolerant. Oreochromis mossambicus is known to tolerate full strength seawater (Green 1997) and red tilapia with Mozambique tilapia heritage can be cultured in full strength seawater. The Florida and Taiwanese strains of red tilapia both grow equal to or better in seawater than in freshwater (Watanabe et al. 1997; Liao and Chang 1983). Florida red tilapia can reproduce in salinities up to 36 g/l, however, egg fertilization, egg hatch, and survival of larvae is highest at 12 g/l and drops markedly after 18 g/l (Watanabe et al. 1997). Nile tilapia are not as salinity tolerant as red tilapia hybrids with a genetic component from Mozambique tilapia. Nile tilapia can be adapted to 25 to 30 g/l saltwater but growth is inhibited in salinities above 15 g/l (Popma and Lovshin 1996; Suresh and Lin 1992). Nile tilapia is reported to spawn in salinities above 20 g/l but egg hatch is reduced in salinities above 10 g/l compared with hatch rates in freshwater and 5 g/l salinity (Watanabe et al. 1984).

Tolerance to Low Water Temperatures

Nile and Mozambique tilapias can withstand minimum water temperatures of 10 to 11°C for several days while the Blue tilapia can withstand 8°C for several days (Popma and Lovshin 1996). The original Florida red tilapia hybrid is not cold tolerant. Growth of the Florida red tilapia in water with 18 and 36 g/l salinity was much lower at 22°C than at 27 and 32°C. Incidence of disease was higher when water temperatures dropped below 22°C and death occurred to some fish at temperatures below 16°C (Watanabe et al. 1997). El Gamal (1987) found that cold tolerance of red tilapia hybrids in freshwater was not significantly different from their ancestors. The water temperature at which 50% of pure O. aureus and red tilapia with O. aureus ancestors died was 7.3°C while 50% of pure O. niloticus and a red O. niloticus hybrid died at 8.2 and 8.9°C, respectively. Halstom (1884) compared the cold tolerance of pink, pink mottled red, red, rust and wild color phenotypes of F1 Florida red hybrids with their O. mossambicus and O. hornorum parents. Tests were also run with off-spring from F1 Florida red hybrids crossed with O. niloticus and O. aureus. Studies were done outdoors in tanks filled with freshwater. Halstrom found no difference in cold tolerance among the Florida red hybrid phenotypes and their parents. Almost complete mortality occurred among the Florida red hybrids and their O. mossambicus and O. hornorum parents during a 12-day period when minimum water temperatures ranged from 11 to 16°C. Red tilapia with a Nile tilapia parent and Nile tilapia experienced about 50% mortality during this same time period. High mortality was experienced in the Florida red hybrids with an O. aureus parent and O. aureus when water temperatures reached 9°C, about 1 month after the Florida red hybrids and their O. mossambicus and O. hornorum parents began dying. Hopkins et al. (1985) wrote that the
Taiwanese red tilapia had significantly lower survival in 19 to 20°C seawater than *O. aureus* or *O. spilurus*, a salinity tolerant tilapia related to *O. mossambicus*. Florida red tilapia are more resistant to low water temperatures in 5 to 12 g/l salinity than in freshwater or full strength seawater (Watanabe *et al.* 1997). Lahav and Ra’an’an (1997) tested the growth of a red tilapia with *O. mossambicus* genes in cages placed in the Mediterranean Sea (37 g/l salinity). Growth slowed significantly when water temperature dropped below 25°C and stopped at water temperatures below 21°C. Crossing Florida red hybrid tilapia with *O. aureus* improves the cold tolerance of the red off-spring compared with cold tolerance of the Florida red hybrid parents (Behrends and Smitherman 1984).

**Spawning and Nursery Performance**

Techniques for spawning red tilapia are the same as those used for other tilapias in the genus *Oreochromis*. Methods of reproducing *Oreochromis* sp. are well documented (Green *et al.* 1997; MacIntosh and Little 1995). Major disadvantages of red tilapia culture are the difficulty spawning some strains of red tilapia and the low viability of red tilapia eggs and fry. Hulata *et al.* (1995) compared the reproductive success of red *O. niloticus* from Egypt and red *O. niloticus* from the Philippines crossed with either pure *O. aureus* or *O. niloticus*, and *O. aureus x O. niloticus* hybrids in earthen ponds. The red Egypt *O. niloticus x O. aureus* yielded only a small number of off-spring but all the off-spring were males. No differences were noted for the number of off-spring produced among the other red and wild-type hybrid crosses tested. Survival of all-red tilapia hybrids was lower than survival of *O. aureus x O. niloticus* hybrids during the nursery phase. The reason for the poor reproductive performance of the red Egypt *O. niloticus x O. aureus* was thought to be caused by behavioral differences during courtship that limited spawning. Low survival of juvenile red tilapia hybrids compared with wild-colored hybrids was because of bird predation on the easily seen red fish.

Siddiqui and Al-Harbi (1995) evaluated pure Nile, blue and Mozambique tilapias, the Taiwanese red tilapia and a Nile x blue tilapia hybrid for freshwater tank culture. Survival from fry to 250 g for hybrid tilapia, Nile tilapia, blue tilapia, Mozambique tilapia and red tilapia was 80, 74, 72, 61 and 7%, respectively. Most red tilapia died during the 112-day rearing period from fry to 30 g and was related to genetic factors. No difference in survival was noted among the pure tilapia species, the tilapia hybrid and the red tilapia during growout from 30 g to 250 g when survival was above 96% for all tilapias tested.

Huang *et al.* (1988) noted that some pink fry phenotypes from back crosses of Taiwanese red tilapia with there off-spring were subviable, less vigorous and showed some deformities when compared with red and wild-colored siblings from the same mother. Watanabe *et al.* (1997) mentioned that fry survival of Florida red tilapia cultured in brackish water is low and that cannibalism is the principal cause of poor survival. Fry survival was increased when eggs were taken from mothers and artificially incubated. Increase in survival of fry from artificially incubated eggs compared with fry hatched from maternally incubated eggs was thought to be caused by more uniform fry size and early feeding of formulated diets to fry from artificially incubated eggs, reducing cannibalism among siblings. Behrends *et al.* (1982) inbred F₁ hybrids from the *O. mossambicus x O. hornorum* Florida red tilapia. F₂ hybrids were separated into 6 phenotypic color types, which included dark, copper, red with black spots, red and pink, pink, and
white. Behrends et al. noted that fry mortality was high in red and pink, and pink phenotypes and all the white fish died before reaching 5 g. Behrends et al. suggest that high fry mortality was due to inbreeding and associated segregation of genetically inferior phenotypes. Shepperd (1984) grew sex-reversed Florida red tilapia and Nile tilapia from 1 g to 40 g in plastic pools. Survival at harvest averaged 86 % for red tilapia and 95 % for Nile tilapia. Deaths of red tilapia were not associated with predation or diseases.

Behrends and Smitherman (1984) had difficulty hybridizing female *O. aureus* with the male Florida red hybrid. Only 2 spawns composed of several hundred fry each were obtained after repeated attempts to spawn the fish. Behavioral or other reproductive isolating mechanisms were blamed for the lack of spawning. However, when the F₁ hybrids from the *O. aureus* x Florida red hybrid cross were backcrossed with female *O. aureus*, normal numbers of fry were produced. Pruginin et al. (1988) working in Israel noted that fry survival of the Taiwanese (*O. mossambicus x O. niloticus*), Singapore (*O. mossambicus*) and Philippine (*O. mossambicus x O. niloticus*) red tilapias was lower than fry survival of pure line *O. niloticus x O. aureus* hybrids. Red tilapia fry number must be 40 to 50 % greater than *O. niloticus x O. aureus* fry number to compensate for lower survival of red fry and assure that enough fingerlings are available for stocking grow-out ponds.

El Gamal (1987) compared hatching success of eggs taken from the mouths of incubating red *O. aureus*, red *O. niloticus*, normal colored "dark" *O. aureus* and normal colored "dark" *O. niloticus* females. Eggs were incubated artificially and eggs from red females were microscopically separated into dark and red colored embryos and each was incubated separately. Average hatch of eggs from red and dark *O. aureus* and red and dark *O. niloticus* was 54 and 83 % and 67 and 81 %, respectively. Dark and red eggs from red *O. aureus* females had 64 and 43 % hatch while dark and red eggs from red *O. niloticus* females had 72 and 61 % hatch, respectively. Fry survival from hatch to 21 days did not differ between species or among species and their red hybrids.

Carberry and Hanley (1997) and Gonzalez (1997) describe the red tilapia culture industries in Jamaica and Colombia, respectively. Carberry and Hanley note that only 32% of fry and juveniles survive to the grow-out phase. Most mortality is due to predation by birds even though sex-reversal tanks are covered with nets and nursery ponds have nylon lines strung across them to discourage wading birds. Gonzalez writes that red tilapia replaced Nile tilapia as the preferred culture fish in Colombia by 1988. Presently, the price of a red tilapia fingerling is 50 % more than a Nile tilapia fingerling of equal size. Poor survival of red tilapia fry and fingerlings due to predation and the need to hold more red brooders than Nile brooders to produce equal fry numbers has increased red tilapia fingerling production costs.

Smith (1996) in Honduras compared reproductive success and fry survival of a red tilapia with genetic components from *O. niloticus*, *O. aureus* and *O. mossambicus* to pure *O. niloticus*. No significant difference was found in reproductive performance and in fry survival during sex reversal between the red tilapia and Nile tilapia. Nile tilapia females yielded 2,701 fry and red females 2,718 fry per kilogram of body weight per 13- to 19-day spawning cycle. An average of 80 % and 77% of the Nile and red tilapia fry, respectively, survived the 14- to 28-day sex reversal period.
Tave et al. (1991) stocked equal numbers of gold, bronze and dark colored *O. mossambicus* fry in concrete tanks with zero, four or eight 25-cm largemouth bass. Overall, bass consumed 52% of the gold fry, 32% of the bronze fry and 32% of the black fry. Tave et al. (1990) stocked equal numbers of gold and dark colored *O. mossambicus* fry together with several densities of predacious dragonfly nymphs. Surprisingly, dragonfly nymphs ate significantly more dark fry than gold fry.

**Grow-out Performance**

Red tilapia are grown to market size using a variety of culture techniques similar to those used to culture pure-line tilapia species. Red tilapia are grown in fresh and saltwater with cages, concrete tanks and earthen ponds using semi-intensive and intensive systems (Watanabe et al. 1997; Carberry and Hanley 1997; Gonzalez 1997). Green et al. (1994) compared the performance of 10 g sex-reversed fingerlings from a mating of Florida red tilapia x *O. niloticus* with wild-type *O. niloticus* stocked at 2/m² in earthen ponds fertilized with chicken manure and chemical fertilizers. Final average weights for red and Nile tilapia were not significantly different but total yield and survival were significantly lower for red tilapia. Average survival of Nile tilapia was 91% compared to 51% for red tilapia. Lower average yield of red tilapia (772 kg/ha) compared with Nile tilapia (1,353 kg/ha) was related to lower survival and not slower growth. Poor survival of red tilapia was blamed on increased bird predation in red tilapia ponds. Green et al. (1994) stocked equal numbers of 10 g sex-reversed red fingerlings from a Florida red tilapia x *O. niloticus* cross and 10 g sex-reversed *O. niloticus* fingerlings together in the same earthen ponds at a density of 2 tilapia/m². Ponds were fertilized with chicken manure and fish were fed a pelleted ration. Ponds were harvested after 148 days and 1,133 kg/ha of Nile tilapia and 456 kg/ha of red tilapia were harvested. Average weights of Nile and red tilapias were 252 and 253 g, respectively. Again, low survival of red tilapia, 37%, compared with 83% survival for Nile tilapia was the cause of the low red tilapia yield. Although red and Nile tilapia were stocked together in the same ponds, bird predation was the major cause of low red tilapia survival.

Pruginin et al. (1988) compared the growth of Philippine red tilapia (*O. mossambicus x O. niloticus*), Singapore red tilapia (*O. mossambicus*) and wild-type *O. niloticus x O. aureus* hybrids in 500 m² plastic lined earthen ponds stocked with 30 tilapia/m². The 3 tilapia strains were stocked together in the same ponds. Ponds were filled with brackish water and provided with aeration and 1 to 10% water exchange per day. Ponds were harvested after 160 days and specific growth rates for Philippine red, Nile x Blue tilapia hybrids and Singapore red tilapias were 3.22, 2.56 and 1.43 percent per day. The Philippine red tilapia grew from 10 g to 240 g while the *O. niloticus x O. aureus* hybrid grew from 20 g to 190 g. The growth rate of the Singapore red tilapia was slow and further studies with this fish were abandoned.

Hulata et al. (1995) compared the growth of 6 strains of colored tilapia containing Mozambique, Nile and blue tilapia ancestry with a normal colored Nile x blue tilapia hybrid. Male tilapia with an average weight of 200 g were tagged to identify strains and stocked together at 0.62 fish/m² in 400 m² ponds filled with freshwater. Ponds were also stocked with common and silver carps. Tilapia were fed a 25% protein pellet for 100 days. Five of the 6 colored tilapia strains grew faster or equal to the normal colored Nile x blue hybrid. Growth rates of the Nile x blue hybrid and 5 fastest growing colored tilapia ranged between 3.0 to 4.3 g/d.
Behrends et al. (1982) stocked mixed-sex Florida red tilapia hybrids and mixed-sex blue tilapia with average weights of 56 and 67 g, respectively, into floating cages at 400 fish/m$^3$. Fish were fed a floating pellet for 128 days. Yield and survival for blue and red tilapias were 127 kg/m$^3$ and 99% and 98 kg/m$^3$ and 96%, respectively. Final mean weight was 322 g for male and female blue tilapia and 256 g for the male and female Florida red tilapia and was the major cause for the difference in total yield per cage. However, the fastest growing fish were the male red tilapia (435 g) followed by male blue tilapia (388 g), female blue tilapia (254 g) and female red tilapia (173 g).

El Gamal (1987) stocked 4 to 7 g sex-reversed pure Nile tilapia, pure blue tilapia, pure O. niloticus female x red O. niloticus male hybrid (Nile hybrid) and red O. aureus hybrid female x pure O. aureus male (blue hybrid) tilapias into earthen ponds at 0.38 fish/m$^2$. The hybrid tilapias had both red and normal colored off-spring. Ponds receiving hybrid tilapia were stocked with 75 normal and 75 red colored off-spring. Fish were fed a pelleted diet for 93 days. Average weights of blue, blue hybrid, Nile and Nile hybrid tilapias were 196, 196, 231 and 262 g, respectively. Nile and Nile hybrid tilapias grew faster than their blue tilapia counterparts. No difference in growth was noted between blue and blue hybrid tilapias while the Nile hybrids grew faster than the Nile tilapia. Normal and red colored blue hybrids averaged 209 and 181 g while normal and red colored Nile hybrids average 281 and 240 g.

Hopkins et al. (1985) compared the growth of 1 to 3 g sex-reversed O. spilurus, O. aureus and Taiwanese red tilapia hybrids in 2m$^3$ circular tanks filled with 38 to 40 g/l salinity seawater in Kuwait. Tanks were provided with water exchange and aeration and were stocked with 100 tilapia/m$^3$. Fish were fed a 40% crude protein diet for 226 days. Average harvest weights of the red tilapia, O. spilurus, and O. aureus, were 132, 80 and 33 g, respectively. The Taiwanese red tilapia grew fastest of the three tilapia species tested but 38% survival forced the authors to reject the red tilapia as a culture species. Low survival of the red tilapia was caused by stress from 19 to 20°C water during the winter months.

Macaranas et al. (1997) on Fiji Island evaluated the production performance of mixed-sex O. mossambicus Israel O. niloticus, Thailand O. niloticus and Taiwanese red tilapia hybrids in 4 m$^3$ cages stocked with 25 fish/m$^3$. Cages were placed in both fertilized and unfertilized ponds. Average stocking weight ranged between 3 and 15 g and fish in all treatments were fed a formulated diet for the 4-month experimental period. Average harvest weights from all treatments for Thailand Nile tilapia, Israel Nile tilapia, red tilapia and Mozambique tilapia were 127, 110, 91 and 60 g, respectively.

**Processing and Markets**

The major advantage of red tilapia over Nile tilapia is improved acceptance by consumers. Consumers relate the red color to a number of marine fishes with similar coloration and high market value. Thus, consumers will often pay a higher price/kg for red tilapia than for a Nile tilapia of equivalent weight. Both whole and dressed (gutted and scaled) Nile and red tilapia are sold in the United States. However, a major importer of cultured tilapia in the U. S. has noted a preference by retailers for whole and dressed red tilapia over Nile tilapia (Simon 1997). Tilapia culture industries in Jamaica and Colombia are based almost exclusively on red tilapia even thought initial culture efforts were with Nile tilapia. Consumer preference for whole and gutted
red tilapia and their willingness to pay a high price/kg has eliminated Nile tilapia from most farmers ponds in Jamaica and Colombia (Carberry and Hanley 1997; Gonzalez 1997). Red tilapia also have a clear or white mesentery covering the peritoneal cavity while the mesentery is black in Nile tilapia (Popma and Lovshin 1996). The black mesentery is a hindrance when marketing whole, gutted fish. The black mesentery is easily removed with a brush or high pressure spray but extra cost is involved. However, the market for high value fresh and frozen tilapia filets is growing in the U. S. (Popma and Lovshin 1996). Once the skin is removed from the flesh, red tilapia have no market advantage over Nile tilapia. Some tilapia producers claim that the flesh of red tilapia is whiter than the flesh of Nile tilapia. White fleshed fish are preferred by consumers in the U. S. However, only the most discriminating consumer will note any difference in the flesh color of red and Nile tilapia fillets.

A muddy off-flavor can also be a problem in tilapia flesh (Popma and Lovshin 1996). Many producers think that red tilapia have fewer problems with off-flavor than Nile tilapia but both have equal ability to absorb off-flavors from the water in which they are raised. Off-flavor is more prevalent in tilapia raised in freshwater than in saltwater. Red tilapia strains with *O. mossambicus* heritage are more salt tolerant than Nile tilapia and preferred for culture in saltwater. Thus, red tilapia are perceived to have fewer problems with off-flavor than Nile tilapia but this is only true because more red tilapia are grown in saltwater than Nile tilapia.

**CONCLUSIONS**

Consumers from many locations round the world demonstrate a clear preference for red colored tilapia over the darker colored Nile tilapia. Unfortunately, in most culture situations red tilapia do not perform as well as Nile tilapia. The difference in culture performance is especially notable in freshwater. Red tilapia with *O. mossambicus* ancestors perform better than Nile tilapia in salinities over 10 g/l because they are more salt tolerant than Nile tilapia. Female spawning success in some red hybrid strains is lower than Nile tilapia and survival of eggs and fry is almost uniformly lower in red tilapia than in Nile tilapia. Reasons for poor survival of red tilapia eggs and fry is caused by increased predation on easily seen red fry, increased cannibalism on red fry by normal colored siblings and low genetic viability in some color phenotypes. White and pink colored fry seem especially susceptible to low genetic viability. Low viability of eggs and fry is compounded by the continual inbreeding of stocks to improve color and eliminate fingerlings with dark and red with black spotted body colors. Farmers can select the most colorful fish for breeding and over a number of generations inbreeding their tilapia, improve the purity of red off-spring. However, constant inbreeding also appears to select for strains of red tilapia with poor egg and fry viability. The author observed red tilapia farmers in Honduras that crossed Nile tilapia females with red tilapia hybrid males to improve fry viability. Nile x red tilapia hybrids yield 50 % red and 50 % dark off-spring. Farmers would manually select only red off-spring for culture and the dark off-spring were discarded. Farmers were willing to eliminate 50 % of the fry produced and accept the costs associated with this practice because the red fry grew to fingerlings that were stronger, had better survival during growout and grew faster than their red tilapia parents. Tilapia farmers often need 2 to 3 times more red tilapia broodstock than Nile tilapia broodstock to produce an equivalent number of fry. Costs of producing red tilapia fingerlings are commonly higher than for Nile tilapia fingerlings because of high egg and fry mortality. Viability of eggs and fry can be
improved by producing and culturing only F1 hybrids from red parents of known heritage and culture performance.

Juvenile and adult red tilapia are highly susceptible to predation by birds. Red tilapia typically swim just under the water surface where they are easily seen by birds. The culture of red tilapia in large ponds may not be possible without covering the ponds with expensive netting or shooting the birds, many of which are protected by law. Small ponds, raceways and cages used to intensively culture red tilapia are easily covered with netting and bird predation can be eliminated. Mortality of red and Nile tilapia during growout from juvenile to market size should be equal where bird predation is eliminated.

Some red tilapia, especially those strains with *O. mossambicus* or *O. hornorum* ancestry, are not as tolerant of cold water temperatures as Nile tilapia. The original Florida red tilapia hybrid (*O. mossambicus* x *O. hornorum*) and Taiwanese red tilapia hybrid (*O. mossambicus* x *O. niloticus*) do not grow or handle well in water temperature below 22°C. Adding *O. aureus* genes to red tilapia susceptible to cold water temperatures will improve the cold tolerance of the red off-spring. Cold tolerance of red tilapia with at least 50% of its genotype from blue tilapia is better than most Nile tilapia strains.

Growth of red tilapia appears to be equal to or better than Nile tilapia in most cases in both fresh and saltwater. The one exception is a red tilapia hybrid with a high percentage of *O. mossambicus* and/or *O. hornorum* genes grown in freshwater. Mozambique tilapia is known to grow slower and mature at a younger age than Nile tilapia (Popma and Lovshin, 1996). Low yields from ponds with red tilapia are generally not due to slow growth but to low survival because of bird predation. The addition of Nile tilapia genes to a red tilapia hybrid appears to improve growth potential, especially in freshwater.

Another spoken but untested advantage of red tilapia is their docile nature which improves capture with a seine from culture units and reduces injury during transport and when cultured in cages. Nile tilapia are nervous by nature and difficult to capture with a seine from earthen ponds because they panic and swim under or jump over the net. The Nile tilapia's ability to escape capture is a serious liability when culturing them in large ponds. Red tilapia are more passive during harvest and are not as adept at escaping the seine by jumping over or swimming under it. Red tilapia are also reported easier to transport alive long distances. Nile tilapia injure themselves by swimming and jumping wildly during loading into and harvest from the transport tank. Similar behavior by Nile tilapia during sampling and partial harvest from cages also results in injury. Injured fish have a higher incidence of mortality after handling.

Many consumers prefer and are willing to pay a higher price for red tilapia than Nile tilapia. The product form sold must have the skin on to take advantage of the red coloration and attract consumers. Skinless product forms from red tilapia, such as fillets, have no market advantage over the same product form from a Nile tilapia. Freshwater fish farmers should culture Nile tilapia when the final product form is a skinless fillet. Fewer problems will be encountered growing Nile tilapia and the cost of growing a kilogram of Nile tilapia is generally less than a kilogram of red tilapia. The higher production cost of red tilapia may not hold true in saltwater as Nile tilapia does not grow as well in high salinity water as some strains of red tilapia.
The choice of red tilapia or Nile tilapia for culture will depend mainly on marketability and water salinity. Red tilapia is preferred where consumers are willing to pay a higher price for a red tilapia than for a Nile tilapia and/or culture will be in water with salinity above 10 g/l. Nile tilapia is preferred where consumers show no preference for and/or are unwilling to pay a higher price for a red fish, the final product form is a skinless fillet, or culture will be in fresh or low salinity water. The selection of a red tilapia for culture is further complicated by the multitude of red tilapia hybrids available round the world. Rarely, is the genetic makeup of the red hybrid or its reproductive and culture performance known. Few laboratories have the capability to accurately identify the genetic makeup of red tilapia hybrids by electrophoretic or DNA analysis. Most tilapia farmers do not understand that poor viability of eggs and fry is a common problem with red tilapia. Farmers blame poor fry survival on bad water quality, disease and nutritional problems when the real cause is often inbreeding and poor genetic heritage. Scientific testing of reproductive and culture performance of red tilapia strains is needed but not widely available. Thus, farmers will have to depend on word of mouth and published literature to find a dependable red tilapia.

Nile tilapia is the species of choice in most freshwater culture situations. If red tilapia is selected because of consumer preference, production costs for a kilogram of red tilapia will likely be higher than for a kilogram of Nile tilapia and market price for red tilapia should be higher to reflect higher production costs. Farmers should carefully evaluate the advantages and disadvantages of red or Nile tilapia under their market and culture conditions before selecting either for culture.

ACKNOWLEDGEMENT

Portions of this paper were presented at the Second Symposium on the Management and Nutrition of Fishes held in Piracicaba, SP, Brazil on July 22 – 23, 1998. Financial support for the author’s travel to attend ISTA comes from USAID Grant No. LAG-G-00-96-90015-00 through the Pond Dynamics/Aquaculture Collaborative Research Support Program. The CRSP accession number is 1180. The opinions expressed herein are those of the author(s) and do not necessarily reflect the views of the U.S. Agency of International Development.

REFERENCES


Halstrom, M. L. 1984. “Genetic Studies of a Commercial Strain of Red Tilapia”. M. S. Thesis, Department of Fisheries and Allied Aquacultures, Auburn University, Alabama 36849, USA.

Hopkins, K., M. Ridha, D. Leclercq, A. A. Al-Ameeri and T. Al-Ahmad. 1985. “Screening of Three Tilapias for Sae Water Culture in Kuwait”. International Center for Living Aquatic Resources Management, MCC P. O. Box 1501, Makati, Manila, Philippines. No. 152.


Popma, T. J. and L. L. Lovshin. 1996. “Worldwide Prospects for Commercial Production of Tilapia”. R and D Series 41, International Center for Aquaculture and Aquatic Environments, Department of Fisheries and Allied Aquacultures, Auburn University, Alabama 36849, USA.


Smith, E. S. 1996. “Factors Affecting Sex Reversal of Tilapia: Species Characteristics and Feed Storage Conditions”. M. S. Thesis, Department of Fisheries and Allied Aquacultures, Auburn University, Alabama 36849, USA.


Wardoyo, S. E. 1990. “Effects of Different Salinity Levels and Acclimation Regimes on Survival, Growth, and Reproduction of Three Strains of *Tilapia nilotica* and a Red *T. nilotica* Hybrid”. Ph. D. Dissertation, Department of Fisheries and Allied Aquacultures, Auburn University, Alabama 36849, USA.
