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An insight to reproductive biology of tilapia

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Introduction

Aquaculture is the highly dynamic and emerging cheapest protein food production sector which helps to improve the economy in many areas of the world. In 2022, the global production of aquatic animals reached a new record height of 185 mmt (live weight equivalent), an increase of 4 percent from 2020. Production from marine areas was 115 mmt (62 percent of the total), of which 69 percent was from capture fisheries and 31 percent from aquaculture. On the other side, inland fish production sector contributed 70 mmt (38 percent of the total), of which 84 percent was from aquaculture and 16 percent from capture fisheries. Among the aquaculture species, tilapia is the topmost farmed fish, after carps, and its production is steadily increasing at global level. Moreover, tilapia is considered as the most widely consumed food fish globally.

Tilapia holds significant value in tropical and sub-tropical aquaculture. Even though they are native to Africa and the Middle East, presently it is farmed in over 135 countries, making tilapia as the geographically most widely farmed fish species. Besides this, it is playing a significant role in both economy and supplying cheaper animal protein. Typical aquaculture traits such as resistant to stress, faster growth rate and easier reproduction in a variety of environments situation are further elevating the tilapia industry at global level. In general, tilapia exhibits gender based growth variations where male attains marketable size in a shorter duration which leads to the production of male monosex population of tilapia. In tilapia farming, controlling reproduction in farming conditions is important to prevent overpopulation, as tilapia can reproduce quickly. Therefore, understanding the reproductive biology of tilapia helps the farmers to do tilapia farming in a better way by stocking monosex seed to control reproduction and to optimize growth rates.

Commercially important tilapia species

Oreochromis niloticus (Nile tilapia), *Oreochromis mossambicus* (Mozambique tilapia), *Oreochromis aureus* (Blue tilapia), *Oreochromis hornorum* (Zanzibar tilapia), and *Oreochromis hybrids* (Red tilapia) are the main cultivable species of tilapia. Globally, Nile tilapia is the most commonly cultured species which alone contributes more than 90% of all tilapia produced for commercial purposes outside of Africa. On the other side, red hybrid strain of tilapia which looks similar to the marine red snapper has also rapidly attained high market value and popularity among the tilapia aquaculturists. Recently, Genetically Improved Farmed Tilapia (GIFT), an improved strain of Nile tilapia, is promoted among tilapia farmers as they grow faster than other tilapia species. Presently, GIFT is also one of the most-farmed fish, next to Nile tilapia, among the farmed tilapia varieties.

Sexual differentiation of tilapia

In tilapia, sexes are separated, and males

Female (top) and male (bottom) GIFT tilapia

Left (female) Right (male)

and females are easily sorted by seeing their gonopore. The structure of anal papilla serves as a visual sex indicator in tilapia. In female, the opening of oviduct can be seen while it is not present in the male. The secondary sexual organ that is located behind the anus also helps in the differentiation. Simple papilla can be seen in male and the female has a wider papilla that has a wide opening for the ejection of eggs during mating.S

Gonadal maturity stages in tilapia

Tilapia attains sexual mature at the age of 4-5 months (10-17 cm length) in farm conditions. On the other hand, the wild populations sexually mature after reaching a size of 20-39 cm. The sexual maturity of tilapia depends on factors like environment, size and age. The following table depicts the maturity stages recorded in tilapia fish.

Table 1 Maturity stages recorded in tilapia fish

Maturity stages		**Testis characteristics**	**Ovary characteristics**
Male	**Female**		
Immature	Immature	Testis not fully developed and appears in form of threads	Flesh coloured, thin and short
Inactive-I	Maturing	Transparent; testis filled with primary germ cells, spermatogonia, spermatocyte s and few spermatids; slightly longer than stage 1	Cream coloured, translucent and elongated
Inactive-II	Mature	Testis become opaque	Light yellow with red hue
Inactive - active	Ripenin g	Testis filled with ripe spermatozoa; appears white	Bright yellow
Active - ripe	Ripe	Cream colored, thick and enlarged	Dull yellow with oval or pear-shaped oocytes
Ripe	Spawning	Distended fully over visceral cavity, milt oozes out if testis cut	Dull yellow, flaccid with large yellow oocytes
Ripe - running	Spent	White/silver y, milt runs freely under pressure	Flesh coloured, flaccid and shrunken

Reproduction in tilapia

Being a prolific breeder, tilapia breeds throughout the year under any favorable environmental conditions. Among the tilapia, two types of breeding behaviors have been noticed. For example, species comes under *Oreochromis* and *Sarotherodon* display mouth brooding pattern in which either female or male incubate their eggs in mouth. On the other side, *Tilapia* species exhibit substrate spawning behavior. In general, the male tilapia builds nest (breeding territory or lek) on the bottom of water during courtship. In the lek or nest, particular male does not allow other males to enter in its territory. During mating, the male induces female fish to lay eggs in the nest and followed by the release of eggs, the male tilapia fertilizes them with milt. Then the fertilized eggs are collected either by females or males (depend on genus) in their mouth and incubated until egg hatches out. Further, parental care will be displayed by tilapia until the fry consumes the yolk sac. Because of oral incubation, the number of eggs per oviposition is fewer than in other fish species. However, the number of eggs produced is also determined by the female's weight. A normal brooder with 1 kg of weight may release 4500-6000 eggs per reproduction cycle. The incubation period varies from 4 to 10 days depending on temperature. At 20℃, it takes about 6 days for incubation, 4 days at 28℃, and 3 days at 30℃. After yolk sac absorption stage, the larvae are referred as swim up fry and start feeding. During oral incubation period, feeding will be stopped by the female tilapia which leads to weight loss in female tilapia.

Tilapia nest (Source: https://fishconsult.org)

Female tilapia with eggs

Reproductive cycle and embryonic development stages

Female tilapia takes about one month to complete one reproductive cycle which includes

Groups	Stages	Description
Embryonic development	Zygote(Z)	✓ A banana yellow ellipsoidal egg weighing 0.008g
	Cleavage(C)	✓ 2 cells, a greenish brown egg ✓ 4 cells ✓ 8 cells ✓ 16 cells ✓ 32 cells
	Blastula(B)	✓ This is characterized by an epithelial layer called the blastoderm in which the germination points in an ovum where the embryo start develops.
	Gastrula(G)	✓ The blastoderm became more visible and formation of germ ring takes place.
	Segmentation(S)	✓ The blastoderm became more visible and Development of rod-like structure known as notochord seen at dorsal part of developing embryo. ✓ The number of somite's increased
	Pharyngula(P)	✓ From the externally visible anterior tissue band, located in the bottom of early brain give rise to the formation of the head and neck. ✓ Appearance of the developing structure of the head and neck ✓ The structure of the head became visible, the heartbeat and blood circulate within the developing embryo which is still enclosed in the chorion.
	Hatching(H)	✓ Break-off of the embryo out of the chorion, eyes and hair-like tail appeared, head appeared. ✓ Distinct heart was visible and functions actively.
Larval development	Early larva (EL)	✓ Yolk absorption, the eye is well developed, and the larvae gradually began to move its jaw. ✓ yolk sac size reduction
	Late larva (LL)	✓ Yolk sac is fully absorbed and the swim up fry had developed to a level that supplementary food can be ingested through which is ready for monosex seed production.

oral incubation of eggs, nursery rearing of young fry, recovery phase of ovary and period of courtship and mating.

All male tilapia production

The major problem faced in tilapia farming is the uncontrolled reproduction of tilapia in farmed conditions which affects the overall growth and profitability of tilapia farming. Besides this, male displays faster growth rate and uniform size and all these factors led to the development of mono-sex male tilapia culture. Monosex seed production or farming method are achieved by implementing various methods such as manual separation of sexes, environmental manipulation, hybridization, sex reversal using hormones and genetic manipulations (androgenesis, gynogenesis, polyploidy and transgenesis).

The most commonly used sex reversal method is the hormone augmentation by androgenic hormones. In general, sex reversal can be done by oral administration of the feed incorporated with androgenic hormones. If the larvae are fed with male hormone (17α methyl testosterone), the fish develops into phenotypic

male which physically display male traits and possess female genotype (XX) and if the larvae are fed with female hormones (estradiol), the fish will develop into phenotypic female physically and functions as female but possess male genotype (XY). This process is referred as sex reversal.

Probably the most feasible and successful way to produce completely male tilapia is to use oral administration of 17 α methyl testosterone-incorporated feed for 21-28 days. However, the extensive use of sex reversal hormones in hatcheries may put workers' health at risk and the natural ecosystem at danger.

Factors affecting reproduction

Environmental factors such as temperature, salinity and light affect fecundity, hatching and development. Optimum temperature for breeding of tilapia is reported as 20-23℃.However, tilapia breeds throughout the year in tropical regions but in sub-tropical region reproduction does not take place during cold months. It is found that photoperiod stimulates breeding, except for *Tilapia zilli*, which delays its sexual maturity when exposed to strong illumination of light. Fecundity decreases when the salinity rise above 20 ppt. Ideal salinity for breeding of tilapia is 10-13 ppt.

Conclusion

Tilapia which is known for its high reproductive efficiency plays a major role in aquaculture. The fast growth rate, environmental adaptability and the reproductive strategy of tilapia makes them ideal for farming. However, the high reproductive efficiency may lead to stunted growth that poses a challenge for aquaculture operations. Therefore, careful understanding and management of tilapia reproduction in farming conditions will play a significant role in successful operation of aquaculture productions units.

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