Curbing the Menace of Prolific Breeding in "Aquatic Chicken" (Tilapia): A Way out to Improve Fish Production in Nigeria

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Abstract: Global aquaculture production has been growing steadily since mid 1990s and in Africa, Nigeria is one of the significant strongly growing producers. Despite the increase in aquaculture production in Nigeria, the country still remains a net importer of fish therefore there is need for intensification and diversification. Clariids represents the major species of fish culture in Nigeria and to diversify there is need for development of the culture of other fish species. Development of Tilapia production will enhance the attainment of food security in fish production due to its positive Aquacultural characteristics. However the biological characteristics of early maturity and prolific breeding remain the major challenges in the development of tilapia culture. Though scientists have experimented different ways of managing the menace of prolific breeding but only the culture of "All male Tilapia" seems to be an effective methods of overcoming the menace. Therefore this paper reviews the masculinization techniques used in Tilapia production for preventing overcrowding of the culture medium and ensuring production of marketable sized fish. The challenges facing some of the techniques were also highlighted.
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1.0 Introduction

Fisheries and Aquaculture make crucial contribution to the world's well being and prosperity. Aquaculture is the world's fastest growing food production sector especially when compared with meat from terrestrial farm animals (FAO, 2012). Since the mid 1990s, aquaculture has been the engine driving growth in total fish production as capture production has leveled off. Its contribution to world total fish production climbed steadily from 20.9% in 1995 to 32.4% in 2005 and 40.3% in 2010. For human consumption, aquaculture contribution reached 47% in 2010 as against only 9% in 1980 (FAO, 2012). In Africa, Nigeria is now one of the most significant and strongly growing producers in aquaculture. This is the result of growing population and high demand for fish which has positioned the country on a market-driven path (Muir *et al*., 2005). In spite of the remarkable growth of aquaculture in Nigeria, it is a well known fact that it is the largest importer of frozen fish in Africa (Atanda, 2012). To mitigate the ugly situation, aquacultural practices must be intensified. One sure way of ensuring improvement on fish production is by realigning interest in Tilapia production, because it is a very important aquaculture species (Altun *et al*., 2006) whose place has been supposedly occupied by catfish in Nigeria. However, the desirability of monosex populations for Tilapia culture is well established (Lutz, 2001). Thus, this paper reviews the masculinization techniques used in Tilapia production for ensuring adequate population, better size and increased yield of farmed Tilapia.

2.0 Tilapia as an Important Aquaculture Species

A large volume of information through scientific research has already been gathered for Tilapia. Even though Tilapias are alien to many countries, they have received as much attention in the tropics and subtropics as salmonids in the temperate areas (Pradeep *et al.*, 2012). Tilapia is the generic name of a group of cichlids endemic to Africa. The group consists of three aquaculturally important genera – Oreochromis, Sarotherodon and Tilapia. Several characteristics distinguish these three genera, but possibly the most critical relates to reproductive behavior (Popma and Masser, 1999). Tilapias are easily identified by an uninterrupted lateral line characteristic of cichlid family of fishes. They are laterally compressed and deep-bodied with long dorsal fins. Generally, the genus of greatest aquacultural importance is the Oreochromis (Lim and Webster, 2006). Nile Tilapia (*Oreochromis niloticus*) being the most common is easily distinguished from others by the strong vertical bands on its caudal fin. Blue Tilapia (*O. aureus*) possesses interrupted bands whereas Mozambique Tilapia (*O. mossambicus*) has weak or no bands on the caudal fin (Popma and Masser, 1999).

Tilapia can grow up to 500 – 600g in 6 - 8 months and may reach sexual maturity as early as 2 – 3 months of age under normal circumstance. They spawn naturally throughout the year and very little management effort is required to breed these fish (Lim and Webster, 2006). Therefore, the single greatest problem with Tilapia according to Paradeep *et al.* (2011) is their early maturity and prolific breeding. However, Tilapia is most amenable to culture due to simple hatchery technology, high disease resistance, acceptance of many by-products as feed ingredients, high tolerance of low dissolved oxygen condition and relative ease of cultivation (Yosef, 2009). Tilapia's contribution to the protein diet of human population in many areas of the world has prompted the International development agencies to name it as "Aquatic Chicken". Popularity and acceptability of this versatile group of fishes among the world population in the early 1990's made them known as "fish of the 1990's" (Costa- Pierce and Rakocy, 2000). Recently they have been considered as "Food Fish of the 21st Century" (Ramnarine, 2005). In 2007, the production of farmed Tilapia reached approximately 2.5 million tons (FAO, 2009). According to FAO (2008), the world wild catch of Tilapia was superseded by farm raised fish such that 80% of the estimated 3.0 million tonnes produced were farmed.

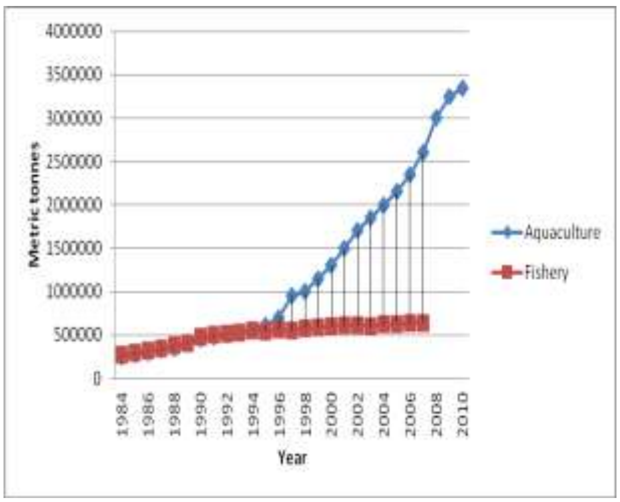

Figure 1: Global Production of Tilapia (1984-2010)
Source: Fitzsimmons (2011)

3.0 Problem of Prolific Breeding in Tilapia Culture

Ideally a fish species used in aquaculture will not reproduce in the culture environment before reaching market size but Tilapias are a paradox in reproduction (Phelps and Popma, 2000). Thus, Tilapia present some challenges to the fish farmer. The relative fecundity of the Oreochromis species is low, 6,000 – 13,000 eggs/kg/spawn. This is often compensated for by high survival of fry resulting from large yolk sac at hatching and mouth brooding maternal care by the parent (Phelps and Popma, 2000). According to Fortes (2005), under favourable conditions, Tilapia will continue to reproduce therefore the offsprings compete with the initial stock for food thereby resulting in stunted growth and unmarketable fish sizes. Several effective methods have been used to control such undesirable Tilapia population and very few have progressed from use in experimental studies or development trials to widespread adoption by farmers (Fagbenro, 2000). According to Fagbenro (2000), the use of local predatory fish species to control undesirable Tilapia recruitment in ponds is one of the most effective and practical methods where a thorough assessment of users (farmer and consumer) perspectives are considered. Even with the use of predators, the main drawback remains the excessive recruitment in ponds, which result in low yields of harvestable size (Mair, 2001). The use of biological inhibitory agents is being advocated (Ekanem and Okoronkwo, 2003). Plants with antifertility properties have been thought of as solution since they are easily obtained and incorporated in Tilapia feed. Some Plants that were tested and proven for antifertility properties include: Pawpaw (*Carica papaya*), Neem (*Azadirachta indica*), Aloe vera (*Aleo barbadensis*), Amargo or bitter wood (*Quassia amara*), Garlic (*Allium sativum*) and Cotton seed (*Gossypium herbaceum*) (Gupta and Sharma, 2006).

4.0 Methods of Maculinizing Tilapia Population

Sexuality of fish has great significance in aquaculture due to the differences in growth rates, survival rate, size, behavior pattern and breeding time (Manosroi, *et al*. 2004). In Tilapia, the culture of all male population is important for higher growth rate and more uniformly sized fish can be obtained (Soto-zarazua *et al*., 2001). This is because the fish exhibits sexually related dimorphic growth in which males grow and reach a larger ultimate size faster than the females (Guerrero and Guerrero, 2001). Taking these into account, considerable work has been done regarding the techniques used for reversing sex in Tilapia, its growth performance and meat quality (Mateen, 2007). The production of a single sex population, especially of male offers several advantages in Tilapia culture including enhanced growth and prevention of precocious reproduction. Four principal methods of producing all-male Tilapia include: Manual sexing, hybridization including environmental manipulation, genetic manipulation and hormonal sex reversal (Fuentes-silva *et al.*, 2013).

4.1 Manual Sexing

Manual sexing of Tilapia fingerlings was widely used in the past. It is an easy technique, but it is extremely labourious, stressful for the fish and often leads to inaccurate results due to the presence of females emanating from human error (Penman and Mc Andrew, 2000). The technique of manual sorting is based on assessing the number of openings in the urinogenital papillae. The male has a single urinogenital opening, while the female has two separate openings. The accuracy of this method ranges from 80% to 90% and increases with an increase in fish size (Penman and Mc Andrew, 2000).

4.2 Hybridization

Hybridization takes advantage of qualitative variance to improve genetics in Tilapia by crossing two closely related but distinct subspecies of fish, table 1 shows some of the species that has been crossed and the result achieved. Generally, such inter-specific hybridization has been used to increase growth rate, manipulate sex ratios, produce sterile progeny, improve flesh quality, increase disease resistance, improve tolerance of environmental extremes (e.g. salinity, temperature) and improve a variety of other traits that make aquatic animal production more profitable. Although inter-specific hybridization rarely results in an F1 suitable for aquatic application there are few significant exceptions (Dunham, 2011).

Table 1: Interspecific Crosses of Tilapias Resulting in All-male Hybrid Progenies

Female	Male	% Males Offspring
O. mossambicus	*O. hornorum*	100
O. niloticus	*O. hornorum*	100
O. niloticus	*O. microchip*	100
O. niloticus	*O. variabilia*	98-100
O. niloticus	*O. aureus*	100
O. spilurus	*O. hornorum*	98-100
O. vulcani	*O. hornorum*	98-100
O. vulcani	*O. aureus*	98-100
O. mossambicus	O. niloticus	100

Source: Atanda, 2012

Hybrids between species can also result in offspring that are sterile or have diminished reproductive capacity. As with monosex production, sterile hybrids can reduce unwanted reproduction or improve growth rate by energy diversion from gametogenesis, and associated behaviours (Baroiller *et al.,*, 1999). The hybrid red Tilapia, a result of cross between *O. mossambicus* (with high salinity tolerance) and *O. niloticus* (with low salinity tolerance) shows enhanced salinity tolerance (Dunham, 2011). Ekaneth and Acosta (1998) indicated that Selective breeding programmes have also been used to improve Tilapia production. Two examples of successful selection programs in Tilapia according to Ekaneth and Acosta (1998) were the ICLARM-coordinated Genetically Improved Farmed Tilapia (GIFT) Project and the Freshwater Aquaculture Center (FAC)–Central Luzon State University (CLSU) Project which produced the YY Super males. The GIFT and the YY Super Males produced through YY male technology are not considered genetically modified organisms. The GIFT Project reported a 70% increase in growth rate over 7 generations of combined selection in a synthetic Nile Tilapia strain developed from newly introduced African and domesticated Asian stocks. The FAC/CLSU Project reported a cumulative response of 18.4% after 16 generations of within family selection using a Philippine strain. The main disadvantage associated with hybridization and selective breeding is the difficulty in maintaining pure parental stock (Fortes, 2005).

4.3 Genetic or Chromosome set Manipulation

The first attempt made on chromosome set manipulation was done in 1975 for blue Tilapia, (*Oreochromis aureus)* using temperature-shocks and it paved way for future investigations on polyploidy in Tilapia.

4.3.1 Androgenesis

Androgenesis is a form of uniparental inheritance in which the female genetic contribution is deactivated and the chromosome complement from the male is doubled. All genetic material is therefore paternal (Mair, 2002). In androgenesis, the maternal DNA in the egg is denatured prior to fertilization by irradiation (UV irradiation, Gamma or X-ray). The fertilized haploid eggs are then subjected to some form of physical shock treatment (cold, heat or pressure) to disrupt mitosis but leaving diploid cells resulting in homozygous androgenic progeny. The disadvantage of this method is that very little success is usually achieved due to the deleterious impact of the shock and the expression of deleterious recessive genes (Tariq Ezaz *et al.*, 2004).

4.3.2 Ploidy manipulation

Ploidy is the number of set of chromosomes in a cell. Polyploids are produced by applying shock to normal fertilized eggs with disruption of meiosis to produce triploid fish (3n) and mitosis disruption to produce Tetraploids (4n) (El Gamal *et al.*, 2007). These methods are also lethal to fish survival and/or development due to the shocks, hence, an alternative approach of inducing triploidy using tetraploid parents has been more attractive. Polyploidy has been well studied in fish. Triploid fish are viable and usually have the attribute of sterility (Pradeep *et al.*, 2012).

4.3.3 Transgenesis

Transgenesis refers to the genomic alteration of an organism by insertion, modification or deletion of a gene with the objective of modifying the trait of interest (Maclean, 2003). Transgenesis has been a major area of fish genetic research since the late 1980s and research in this area is more advanced in fish than other animals (Murphy, 2002). This is because reproductive biology of fish makes them more amenable to induction compared to higher organisms such as poultry or mammals. The main target trait of transgenetic research in fish to date has been the enhancement of growth rate in aquaculture through introduction of growth hormone genes. The principal technique of transferring gene into fish eggs are by microinjection and electroporation of DNA into eggs shortly after fertilization (Rahman *et al*., 2001). Organisms resulting from successful transgenesis are classed as genetically modified or living modified organisms (GMO or LMO) and are thus subject to societal and regulatory concerns as regards ethics, risks to human health and environmental impacts (Galli, 2002). As a result, there are no transgenic food fish currently under commercial production despite proven enhanced performance (Atanda, 2012).

4.4 Hormonal Sex Reversal

Sex reversal using synthetic hormones (Table 2) has been extensively used for sex determination and producing monosex fish for aquaculture purposes (Phelp and Popma, 2000). Wassermann and Afonso (2003) reported that the effectiveness of sex reversal by hormonal treatment depends on the type of hormone, its dosage, time of treatment initiation and its treatment duration. Kobayashi *et al.* (2008) pointed that, the appearance of ovocoel and testocel, indication of sex differentiation to femaleness or maleness takes place 30 to 33 days post hatching in *Oreochromis niloticus*. This is a critical period of sex determination of germ cells in the sexually undifferentiated gonads during which germ cells respond to exogenous as well as indigenous inducers of sex determination in Tilapia (Kuramochi, *et al.*, 2011). Synthetic hormones (androgens) have two physiological actions: androgen activity by promoting development of male characteristics and anabolic activity by stimulating protein biosynthesis. A number of scientists have used the synthetic androgen, 17 alpha-methyl testosterone (MT) for sex reversal in different species of fish at different concentrations and treatment durations (Lopez *et al.*, 2007). Fuentes-silva *et al.* (2013), stated that masculinization is mostly induced with MT, also that dietary treatment and fry immersion are the most acceptable methods for administering steroids. Dosage of 17-alpha methyl testosterone used to produce all-male Tilapia varies widely, 30 to 50mg/kg of feed and the duration of administering MT for masculinizing *O. niloticus* varies from 14 to 60 days (Jimenez and Arredondo, 2000). One standard practice that determines the quantity of hormone to be administered and the length of treatment for sex reversal efficiency in Tilapia have not been well defined (Mateen, 2007). However, Macintosh (2006) described the recommended best practices for MT use in aquaculture as follows:

1. Restrict Tilapia MT treatment to the early fry stages, specifically to the first month from the time the fry are free-swimming/first-feeding.
2. Limit the dosage of MT used to a maximum of 50 mg MT/kg fry feed.
3. Rear MT treated Tilapia fry to adult size for at least five months after hormone treatment ends to ensure zero hormone residue remains in the fish.
4. As a precautionary measure, adopt safe handling protocols when preparing and administering MT treated Tilapia feed; use latex gloves and a protective face mask to avoid dermal contact or inhalation of MT.
5. Keep a careful inventory of the amounts of MT supplied to and used in each Tilapia hatchery, and ensure that access to the hormone supply and record-keeping are controlled by the farm manager or hatchery supervisor.
6. Avoid direct release of hatchery water used for MT treatment of Tilapia fry into the environment. As a precautionary measure, Tilapia hatcheries should utilize a gravel and sand filter, plus a shallow vegetated pond or an enclosed wetland, to receive and hold the hatchery wastewater for several days before discharge into the general environment.

Macintosh (2006) concluded that, there is neither environmental nor health risk associated with the use of the hormone in aquaculture provided the recommended best practices are maintained. But scientists are still concern with the use of synthetic steroids. To further address the concerns about hormone treated fish, Kavitha and Subramanian (2011) had suggested the use of natural substances. In Nigeria, Omitoyin, *et al.* (2013) used a plant extract, *Tribulus terrestris* to induce sex reversal in *O. niloticus* and he suggested that *T. terrestris* can either be added to culture water or administered orally in place of 17 alpha-methyl testosterone to induce sex reversal in *O. niloticus*. Synthetic hormones are more expensive, time consuming and labour intensive when administering as well as requiring high level of expertise when compared to that of local plant extracts. Furthermore, synthetic hormones accumulate in the sediment, water and aquatic biota (Cek et al., 2004). There are also concerns about consumer perceptions of eating hormone treated fish (Phelps and Carpenter, 2002).

Table 2: Steroid hormones, hormone analogues and non-steroid compounds used for producing monosex Tilapia

Hormone (Compound)	Abbreviation
17 alpha-methyl dihydrotestosterone	MDHT
17 alpha-methyltestosterone	MT
17 alpha-ethynyltestosterone	ET
17 alpha-methyl-5-androsten-3-17 beta-diol	
Androstenedione	AN
17 alpha-ethymyloestradiol	EE
Oestradiol-17 beta	E2
Fadrozole	F
Trenbolone acetate	TBA
11 beta-hydroxyandrostenedione	11 beta-OHA4
Aromatase inhibitor	AI
Diethylstilboestrol	DES
Tamoxifen	
Acriflavine	
Mibolerone	MI

5.0 Conclusion

Though different methods of treatment of fish for sex reversal have been experimented, the incorporation of hormone through oral administration has been successful to a greater extent than any other method. But invariably, there has been perceived environmental and health issues related to hormone use i.e possible effects of treatment residues on water quality, biodiversity and consumers' health. Also, considering the growing concerns for food security, finding an effective sex control alternative in fish remains a lingering challenge for aquaculture. This must be based on non-hazardous to consumer and environment friendly methods. Hence, the quest on discovering natural plants that will keep the viability of the sex reversal method as well as eliminate the skepticisms on synthetic hormonal treatments becomes a highly placed option in increasing Tilapia productivity.

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