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Use of Dietary Phytochemicals as control for Excessive Breeding in Nile Tilapia (*Oreochromis niloticus):* A review

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Abstract

Human population has continued to increase unabatedly with its attendant demands on food in order to ease the difficulties of malnutrition and starvation. This continuous rise in population has clearly indicated that the conventional forms of livestock production and captured fisheries will not be sufficient to solve the problem of high protein demands. Aquaculture remains the best option that can bridge the wide gap between human protein demands and domestic production through the culture of fish species like Nile Tilapia (*Oreochromis niloticus*). *Oreochromis niloticus* is one of the most cultured finfish, due to its acceptability as food, fast growth, availability for farmers, ability to breed in captivity, resistance to diseases and harsh environmental conditions. Despite all these outstanding characteristics, there is still high level of apathy in commercial production of Nile Tilapia, due to its precocious maturity and uncontrolled breeding, which results in overpopulation of ponds, stunted growth and low commercial value. To mitigate this challenge, the use of synthetic hormones such as 17α-methyl testosterone has been developed to masculinize female tilapia present in a pond, thereby allowing the production of marketable sized fish since the male grows faster than the female. Though, the use of synthetic hormones has helped in some ways, but the negative effects have necessitated farmers to seek alternatives that are environmental friendly and safe for consumers. Dietary phytochemicals have been established to be good alternatives and their use is now gaining global acceptance. Dietary phytochemicals are bioactive compounds commonly found in plant-based diets such as fruits, vegetables, grains and teas. Dietary phytochemicals when administered to newly hatched tilapia species, influences the undifferentiated gonadal tissue of generic females to develop testicular tissue, thus functioning reproductively as males. Some of these phytochemicals such as Flavonoids, Saponins, Phenolics and Alkaloids are found in plants like *Carica papaya* seeds, *Azadirachta indica*, and *Mucuna pruriens*. The usefulness of these phytochemicals is based on their ability to influence sex reversal in *Oreochromis niloticus*, cost effect, easily accessible especially by small scale fish farmers, simple to apply, and being safe for both human and the environment since they are more biodegradable than synthetic hormones.

Keywords: Bioactive Compound; Monosex; Nile Tilapia; Prolific Breeding

1. Introduction

Human population has continued to increase unabatedly with its attendant demands on food in order to ease the difficulties of malnutrition and starvation [1]. This continuous rise in population, particularly in Nigeria has clearly shown that the conventional forms of livestock production and captured fisheries which has been over exploited will not be sufficient to solve the growing protein insecurity in the country [2]. Therefore, to solve the problem of high demand for protein across the globe and Nigeria in particular, aquaculture remains the best option that can bridge the wide gap between human protein demands and domestic production of animal protein [3, 4].

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Aquaculture is regarded as a key agricultural and food production sector throughout the world, with its production increasing on daily basis as a way to mitigate the shortage of animal protein [5]. Aquaculture entails the farming of aquatic organisms which include fish, molluscs, crustaceans, amphibians and aquatic plants in ponds, tanks, aquaria and other enclosures [6]. For the past two decennium, fish farming has greatly developed globally to become an economically significant industry, with an average annual global growth level of 8.8% per year when compared with all other animal food production sectors [7, 5]. Aquaculture industry is noted to be one of the fastest growing food producing agricultural industries in the world, providing over 47% of the total food fish supply globally [8]. The recent improvement and commercialization of aquaculture as a standout business in many parts of the world could be attributed to its ability to generate income, employment, food and provide the means to revitalize rural living by making fish available for other uses [9].

Figure 1 Aquaculture in Sub-Sahara Africa [5]

Fish is an important dietary source of animal protein in human nutrition, providing essential fatty acids and micronutrients [10]. Fish is ranked as the cheapest source of animal protein which provides high quality calories, fats, vitamins in addition to mineral such as iron and zinc [11]. Particularly, freshwater fishes like Nile tilapia contain saturated fatty acids, monosaturated fatty acids and long-chain poly unsaturated fatty acids that help in prevention of diseases, immune development, control of inflammatory and cardiovascular diseases as well as neurological diseases[12]. The rate of fish consumption in a global context is doubling faster than the global population growth because of awareness of the health benefits associated with fish consumption, and as a result of this, advocacy for the culture of some fish species has been on a high gear [13]. Farming of favoured fish species that could provide complementary sources of animal protein has been widely advocated and among the culturable species of fish in Nigeria which were advocated are Nile Tilapia, Carp and African Catfish [14].

Nile Tilapia (*Oreochromis niloticus*) is one of the most standout cultured finfish globally after Carp, a native to Africa that belongs to the family of *Cichlidae* [15]. *Oreochromis niloticus* is a surface feeding omnivore which contributes significantly to African inland water fisheries [16], a delicious and mild flavoured fish which has become very popular across the globe because of its low price among the consumers [17]. Nile Tilapia (*Oreochromis niloticus*) is known as a wide feeder that feeds on variety of feed substances, with ability to tolerate harsh environmental changes, resistance to disease, breeding in captivity and fast growth rate [18].

Despite all these outstanding characteristics displayed by *Oreochromis niloticus*, there is still high level of apathy in commercial production of Nile Tilapia due to its precocious maturity and uncontrolled reproduction, resulting in increasing competition for feed, space and oxygen which is followed by stunted growth and low commercial value [19, 20, 15]. Due to excessive spawning of Tilapia in ponds that results to overpopulation and consequently drop in water quality, several methods have been developed to control reproduction for cost effective production of Nile Tilapia and one of such methods is the use of hormones to masculinize all female tilapia [21, 22].

Figure 2 Nile Tilapia [5]

1.1. Masculinization of Nile Tilapia

Masculinization of Nile Tilapia is the production of all male populations of Tilapia present in a pond, to inhibit the tendency of overpopulating the pond, thereby allowing the production of marketable sized fish, [15]. Masculinization of female tilapia can be achieved by administering of male steroid to recently hatched fry, so that the undifferentiated gonadal tissue of generic female develops testicular tissue, thus functioning reproductively as males [23]. It is the most effective technique of increasing Nile Tilapia production under commercial culture system, since the production of all male tilapia grows faster than females [24]. According to [25], the male tilapia (monosex fish) has the ability to tolerate harsh environmental conditions such as low dissolved oxygen, high temperature, salinity and a greater uniformity in size of fish is achieved at harvest because there is no waste of energy in gonadal development of the fish. The two commonly used synthetic androgen hormones used to masculinize female tilapia are methyl testosterone and ethynyl testosterone [26].

1.2. Use of Synthetic Hormones/ Steroid

Androgenic anabolic steroid hormone such as 17 α -methyl testosterone is a derivative of testosterone which potentially increases sexual development in males [27]. 17 α -methyl testosterone (MT) is a synthetic product, a methyl derivative of testosterone used in medicine to suppress testosterone deficiency and treat symptoms of andropause in men [21]. Methyl testosterone treatment of Tilapia fry is the most simple and reliable way to produce all male tilapia stocks, which consistently grow to a large and more uniform size than mixed tilapia [24]. The commonly used treatment method is oral administration for periods of 18-60 days in tanks or aquaria with a dosage ranging from 10-60mg/kg in diet, which is widely acknowledged as being effective for sex reversal [26].

In a research carried out by [28] on masculinization of Nile Tilapia through immersion of larva at 36ºC temperature and residue level of 17α-methyl testosterone in fish body, it was observed that the 17α-MT immersed in tilapia larvae, produced males of 91.69 to 98.3%. Similarly, [29] from their work on immersion of 17 α -methyl testosterone dose and duration on tilapia masculinization, reported that oral treatment of 60 mg/kg of 17α-MT feeds, produced males of 93.7%. Also, [20], reported from their work on 17α-methyl testosterone and some medicine plant as reproductive controller agents of *Oreochromis niloticus,* fish treated with 17α -methyl testosterone gave the highest significant values of growth performance, highest male percentage and economic efficiency.

Despite the fact that many studies have acknowledged the use of synthetic steroid hormone like 17α -methyl testosterone as the best technique that offers a practical and economic approach for the control of excessive breeding in tilapia, there is consciousness that the use of large quantities of sex reversal hormone in hatcheries may pose health risk to consumers, aquaculturists and the environment [26, 30]. Similarly, [27], reported that the utility of hormones such as 17 α -methyl testosterone in aquaculture production was often debated by researchers due to the potential toxicity on human health (a carcinogenic and endocrine disorder) as well as the environment. The use of methyl testosterone as reproductive controller agent in *Oreochromis niloticus* production, have been placed under strict restriction in many countries like India and European Union due to the associated ecological and health-related hazards [31]. Apart from the problem of toxicity of this hormone when used in excess, the hormones may be difficult to be obtained in some country, and hatchery facilities and skilled labourers are required [32]. Also, there is still problem of low technological knowledge on the use of sex reversal hormone in Sub-Sahara African like Nigeria and this may create adverse effects since aquaculture is still in the infancy stage in developing countries with poor protective equipment and guidelines on the use of hormones [26] .Therefore, there is need to use alternative method of sex reversal that is

non-hazardous, cost effective, human and environmental friendly. This is where dietary phytochemicals holds much promise.

2. Dietary Phytochemicals and their Sources

Dietary phytochemicals are bioactive compounds that are commonly found in plant-based foods such as fruits, vegetables, grains and tea [33]. Phytochemicals include: Carotenoids, Anthocyanins, Glycosides, Alkaloids, Saponins, Terpenes, Flavonoids, Tannins, Polyphenols [34]. The use of dietary phytochemicals in control of excessive breeding in tilapia culture is novel in aquaculture industry. According to [19], many phytochemicals extracts contained in herbs are reported to stimulate testosterone secretion and improve sexual status, and some of these phytochemicals are present in plants such *as Carica papaya seeds, Aloe vera, Moringa oleifera, Azadirachta indica, Basella Alba, Hibiscus maranthus and Mucuna pruriens.*

2.1. Pawpaw (*Carica papaya*) Seeds

Pawpaw (*Carica papaya*) is one of the economically significant fruit trees in Caricaceae family, with phytochemicals which have attracted research attentions in sex reversal of female tilapia [35]. Pawpaw has been used over the years to induce sterility in laboratory animals, and has as well served as therapeutic plant in rural communities to treat both animals and human diseases [36, 1]. This is as a result of the presence of bioactive compounds such as Chymopapain and Papain, Alkaloid, Saponin, Flavonoid, Tannin, Cyanogenic glycosides, Anthraquinol, Carpine, the enzyme Myrosin and Carpasamin [37, 15].

Proximate analysis of *Carica papaya* dried seed had shown that it contains 97.27% dry matter, 34.80% crude fat, 30.08% crude protein, 7.11% ash, 23.6% nitrogen extract and 1.67% crude fibre, which makes it viable for fish nutrition [38]. In a study carried out by [39], to assess the ability of using pawpaw seed as a natural reproduction inhibitor for tilapia fish culture to control its breeding, it was reported that pawpaw seeds meal induced permanent sterility in the high dose treated fish, while the low dose treated fish showed reversible results. Similarly, [15], reported from their work on masculinization and effect of Nile Tilapia fed with pawpaw seed based diet and steroid hormone, that fish treated with plant extract (pawpaw seed powder) recorded 78.48% male when compared with 17α-MT treatment that recorded 93.40% males. Thus, the level of male percentage in fish treated with pawpaw seed diet, could be attributed to the phytochemicals contents of the diet [30].

Figure 3 Pawpaw seeds

2.2. Neem Plant (Azadiracha indica)

Azadirachta indica which is commonly known as Neem is native to Nigeria, Burma, India and Pakistan, growing both in tropical and semi-tropical regions [40]. Neem is a member of the mahogany family called Meliaceae, with several medicinal properties such as anti-inflammatory, spermicidal effect, anti-fertility as well as abortifacient, and all these properties make the plant a standout potential agent for control of prolific breeding in *Oreochromis niloticus* [41, 40]. Some of the bioactive compounds that account for these properties are Saponin, Flavonoids, Phenolics, Phytates, Alkaloids, Tannin and Ascorbic Acids [42]. Similarly, in a phytochemical screening study on *Azadirachta indica*, [34] reported that extract of Neem such as flavonoids, alkaloids, steroids, saponin and tannin obtained in ethanol, methanol solution had ability for sex reversal in tilapia.

In a study carried out by [41] on anti-fertility effect of some plant leaf extract on the prolific breeding of *Oreochromis niloticus*, it was reported that the number of hatchlings production were significantly reduced for fish treated with *Azardirachta indica* ethanol extracts due to the presence of saponin. The reduction of hatchlings in *Oreochromis niloticus* fed with phytochemical extracts from Neem plant could be attributed to the anti-fertility properties of phyto-compounds like flavonoids, saponins and alkaloids found in this plant [43]. Therefore, aquaculturist can use *Azadirachta indica* to control excessive breeding in tilapia depending on availability of the plant.

Figure 4

Moringa Leaf (*Moringa oleifera*)

Moringa (*Moringa oleifera*) is a multipurpose tree that belongs to family of moringaceae, growing in tropical and subtropical environments with every part of the plant being beneficial [44]. *Moringa oleifera* contains different phyto-compounds in their parts and these include: Phenolics, Tannins, Saponins, Phytates, Lectins and Cyanogenic glycosides, although moringa leaves are free from some anti-nutrients except for Saponin and Phenolics[45]. Dietary moringa leave have been reported to shift tilapia sex ratio in favour of males [26].

2.3. Velvet Beans (Mucuna pruriens)

Figure 5 Velvet Beans

Velvet bean is one legume of great importance that belongs to the family of fabaceae with high nutritional content in terms of protein, carbohydrate and other macro and micro elements [46]. Quantitative phytochemical analysis of raw *Mucuna pruriens* seed, had shown it contains 0.42% of flavonoids, 1.02% of alkaloids, 0.47% saponin, 0.28% of tannins, 2.82% of phenolics, 0.43% of phytates and 12.69 mg/kg of hydrogen cyanide [47].The seed of *Mucuna pruriens* contains prurienine and prurienidine compounds which are known as pro-fertility promoters that stimulate testosterone secretion in men and thereby leading to increase in spermatozoa concentration [48]. The presence of these phyto-compounds had been utilized in masculinization of female tilapia species in experimental trials [26]. *Mucuna pruriens*

had been reported to be effective in masculinization of tilapia species due to the presence of phytochemicals such as Saponin and flavonoids which are able to elevate testosterone hormone production in fish [31].

3. Conclusion

The use of dietary phytochemicals has proven to promote sex reversal in Nile Tilapia as control agent for excessive breeding in ponds. Although the technology is yet to progress from experimental trials to wide spread adoption by farmers for intensive and commercial production of Nile Tilapia. Compared to the use of synthetic sex hormones, dietary phytochemicals are easily accessible especially by small scale and rural fish farmers, cost effective, simple and easy to apply and are safe for both the environment and human as they tend to be more biodegradable. However, the presence of some anti-nutrients in plants had been reported to affect feed utilization and growth. Therefore, studies are necessary for identification and isolation of plant bioactive compounds responsible for this adverse effect for proper utilization of dietary phytochemicals as excessive breeding control agents in *Oreochromis niloticus* production.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there was no conflict of interest.

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