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A REVIEW ON BIOTOXINS AND PESTICIDES AS ENDOCRINE DISRUPTORS ON THE FISH REPRODUCTION

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ABSTRACT

Exposure to low-levels of some chemical the contaminants or xenobiotics present in the wastewater which is released from the industries, houses, agricultural and non-agricultural lands discharges as a source of endocrine-disrupting chemicals to the freshwater, marine water, and brackish aquatic environment shows potential effects on the endocrine system especially disruption of endocrine functions in animals, such as reproduction. This is done by modulating, mimicking, or interfering with normal hormonal activity. The present review shows that the effect of endocrine-disrupting chemicals (Biotoxins and Pesticides) on fish reproductive endpoints including spermatogenesis, steroidogenesis, activities of antioxidants, fecundity potential, egg production, and estradiol levels of male and female fishes. In the present review study, the exposure to pesticides combined with mycotoxins further deteriorated the reproductive endpoints indicating additive effects of these endocrine-disrupting chemicals significantly decreased almost overall reproductive parameters like tissue indices reproductive organs, sperm quantity and quality, steroidogenic enzyme activities, levels of testosterone, histology of testis, lipid peroxidation levels and antioxidant enzyme activities are inflated by pesticides and biotoxins in male and female fishes. It is concluded that these toxicants deteriorate the reproductive ability of male and female fishes.

KEYWORDS: Endocrine disruptors, Biotoxins, Pesticides, Reproductive end points, Fishes.

1. BACKGROUND

Reproduction is the fundamental biological process to generate or create new offspring or generation. Successful reproduction is dependent on the precise timing of neuroendocrine and

behavioral events, as well as optimal environmental and physiological conditions. Infertility is one of the serious ongoing problems all over the world. During the past few decades, there is a gradual increase in reproductive disorders at a rapid rate.

Aquaculture is one of the fastest-growing sectors of world in human food production and has an annual increase of India about 10% (FAO, 1997) in agriculture. It has been demonstrated that reproductive impacts of endocrine-disrupting chemicals like marine biotoxins and pesticides are due to different mechanisms as mimicking or antagonizing hormonal effects, pattern changes of hormones synthesis, and metabolism and modification of hormone-receptor interaction (Grindler et al., 2018; Soto et al., 1995). These perturbations may seriously impact male and female gonadal development and, in humans, in particular, clinical evidence and epidemiological studies have highlighted an association between EDs action and reproductive disorders, such as gametogenesis and gamete quality impairment, fertility rate decrease, endometriosis (Sifakis et al., 2017) as well as testicular and ovarian cancers. Most chemicals present in the aquatic environment exert their effect within the testis during spermatogenesis resulted in malformed sperm and abnormal sperm motility and so affecting fertilizing ability (Kime, 1999).

1. 1. Endocrine Disruptors

There are several factors that pose direct damage to reproductive development in humans and animals. Many scientific investigations reported that exposure to substances (toxicants) in an environment that interfere with the normal function of the endocrine system (endocrine disruptors), and is able to alter the endocrine mediated reproductive function by mimicking or inhibiting the synthesis and/or transport of endogenous hormones. Among these biotoxins and pesticides is one of the most important endocrine disruptors which affect the reproduction in male and female fishes.

1. 2. Marine Biotoxins

The marine environment is quite dynamic compared to freshwater ecosystems and many species of marine microflora produce toxins that have specific effects in other species such as invertebrates, vertebrates in many cases especially on fishes.

Marine biotoxins are natural toxic substances that are produced by a biological origin like fungi, bacteria, algae, plants, animals, and cyanobacteria in marine aquatic environment. Biotoxins can be divided either by source of origin, biological effects, or chemical structure,

and toxins with similar chemical structures may have a different biological origin. Biotoxins in food and feed are also a concern for animal health. There are different types of biotoxins like mycotoxins (produced from fungi), algal toxins (produced from algae), and bacterial toxins (secreted by a bacterium), etc.

1. 3. Biotoxins and Pesticides

Biotoxins and pesticides are major contaminants that commonly co-occur in agricultural products and thus of major concern for human and animal health. The indiscriminate use of pesticides and poor agricultural practices makes the occurrence of these substances above permissible levels in food and feed. The coexistence of mycotoxins, algal toxins, and pesticides in food and in an aquatic environment is associated with a number of physiological alterations and reproductive disorders (Kher et al., 2013).

Fishmeal is an important ingredient of fish feeds, will not be available in sufficient amounts in the future. The ingredients are often contaminated with several mycotoxins and algal toxins. The most 10 commonly and most problematic mycotoxins in cereals and other feed ingredients are Aflatoxin B1 (AFB1), Deoxynivalenol (DON) Nivalenol (NIV), Zearalenone (ZEN), Ochratoxin A (OTA), T-2 toxin (T-2), Fumonisin B1 (FB1), Moniliformin(MON), Enniatins (ENN) and Beauvericin (BEA) and also some algal toxins like Domoic acid (DA), Saxitoxin (STX), Brevetoxin (BTX). Since these toxins are produced by different fungi and algae their occurrence in feed ingredients also varies. Algal toxins are generated during blooms of particular naturally-occurring algal species.

2. OBJECTIVES

This study shows the effects of Biotoxins and Pesticides on the reproductive system in fishes, it also focuses on the histological changes on reproductive tissue in fishes and some aspects of spermatogenesis, fecundity and consequent effects on oogenesis, sperm analysis (sperm count, viability, motility, daily sperm production, sperm function test), steroidogenic enzymatic activities, histology of testes. The present study is focused on the review of biotoxins and pesticides as endocrine disruptors on male and female.

3. TEST CHEMICALS

For the present study, the following Biotoxins like Mycotoxins [Aflatoxin B1 (AFB1), Ochratoxin A (OTA), Zearalenone (ZEN)] and Algal toxins [Domoic acid (DA), Saxitoxin (STX), Brevetoxin (BTX)] and also some of the Pesticides like Dimethoate (DMT),

Malathion (MT), Cypermethrin (CMT) and Chlorpyrifos (CPF) are selected for review to the assessment of reproductive endpoints (Table1).

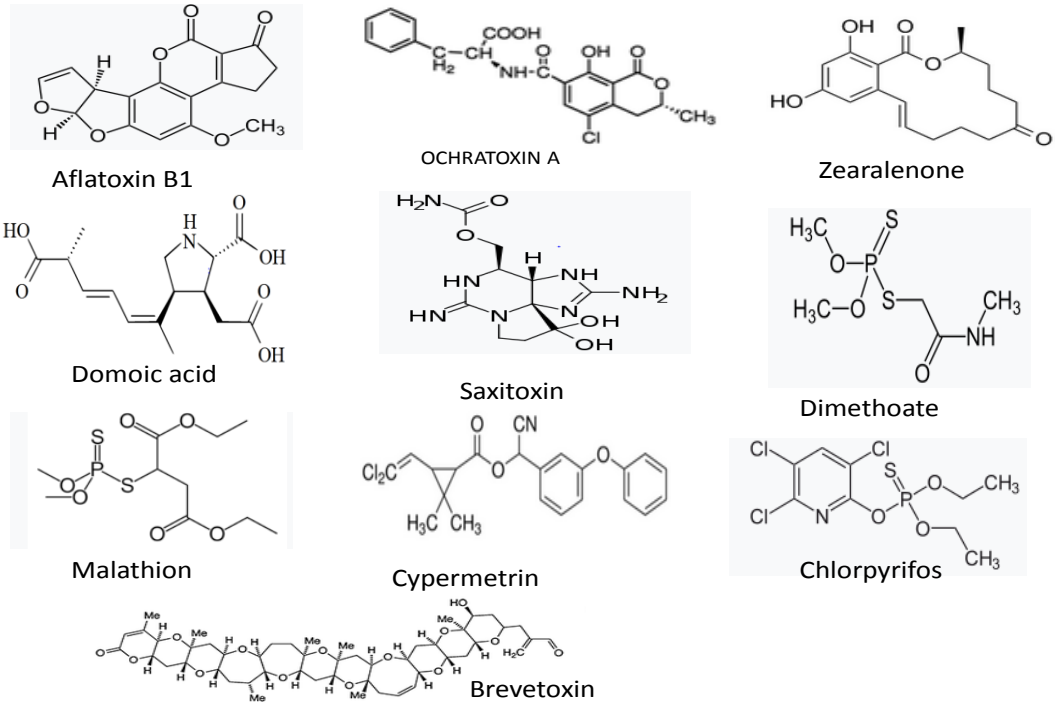

Figure 1: Structures of Biotoxins and Pesticides (collected from pub chem).

Table 1: Information about chemical (Collected from pub chem.).

Biotoxins and pesticides	Chemical formula	CAS Number	Molecular Weight (g/mol)
Aflatoxin B1(AFB1)	$C_{17}H_{12}O_6$	1162-65-8	312.2798
Ochratoxin A (OTA)	$C_{20}H_{18}ClNO_6$	303-47-9	403.813
Zearalenone (ZEA)	$C_{18}H_{22}O_5$	17924-92-4	318.4
Domoic acid (DA)	$C_{15}H_{21}NO_6$	14277-97-5	311.33
Saxitoxin (STX)	$C_{10}H_{17}N_7O_4$	35523-89-8	299.291
Brevetoxin (BTX)	$C_{50}H_{79}NO_{17}S$	79580-28-2	895.08
Dimethoate (DMT)	$C_5H_{12}NO_3PS_2$	60-51-5	229.3
Malathion (MT)	$C_{10}H_{19}O_6PS_2$	121-75-5	330.358021
Cypermethrin (CMT)	$C_{22}H_{19}Cl_2NO_3$	52315-07-8	416.3
Chlorpyrifos (CPF)	$C_9H_{11}Cl_3NlO_3P_1S_1$	2921-88-2	350.6

4. MAJOR FINDINGS (Results and Discussion)

Natural toxins and pesticides can cause a variety of adverse health effects and pose a serious health problem for both humans and livestock. Some of these chemical substances are extremely potent. Fish may be exposed to natural biotoxins and pesticides during the different developmental stages of the reproduction process like sexual maturity, egg and larvae development, the effect of a single chemical toxin is different because the levels of exposure

and the way of the toxic substance may find their target is also different. Most of the natural toxins and pesticides present in the environment in a dissolved state.

The results or data of the present study reviewed from the previous studies related to fish reproductive toxicity. According to a few previous studies related to the effect of mycotoxins and algal toxins also decreases the sperm quality and quantity like sperm count, motility, hypo-osmotic swelling were observed. And also reduced steroidogenesis, increased oxidative stress, decreased steroidogenesis were noticed in all experimental fishes (Table 2).

Gonadal Somatic Index was significantly decreased in Clarias batrachus after 6 months of exposure to pesticide of dimethoate (Begum and Vijayaraghavan 1995). Nile tilapia treated with dimethoate (1.6 mg/kg) and malathion (0.17 mg/kg) showed a significant decrease in gonadal somatic index decreased spermatogenesis, steroidogenesis, and marked histopathological changes after 120 days of exposure (Eman et al., 2011). On the other hand some authors found that gonadal somatic index (GSI) of O. massambicus following exposure to 2µg/l and 5µg/l DDT showed no significant differences compared to control (Mlambo et al., 2009) and also O. niloticus exposed to sublethal concentrations (5, 10 and 15 ppb) of chlorpyrifos- ethyl for 15 and 30 days showed no significant difference in estradiol and testosterone concentration (Ozcan Oruc, 2010). Most chemicals present in the aquatic environment exert their effect within the testis during spermatogenesis resulted in malformed sperm and abnormal sperm motility and so affecting fertilizing ability (Kime, 1999).

Some of the previous studies related to pesticide toxicity on the reproductive system were prolonged exposure of pesticides in different concentrations may increase oxidative stress, decreased spermatogenesis and steroidogenesis in male fishes, and also decreased fecundity in female fishes. One of the recent studies by Ghoda, 2009 reported that prolonged exposure to Cypermethrin (1mg/kg for 45 days) may decrease sperm motility and sperm concentration observed (Table 3).

The present study indicates that exposure to biotoxins and pesticides to fishes which results in a significant decrease in the weights of testes, a significant decrease in the sperm parameters like daily sperm production, epididymal sperm count, motile sperm, viable sperm, and the number of HOS tail coiled sperm and testis volume in all experimental male fishes. And also significant diminish in the activity levels of testicular steroidogenic and estradiol hormones and elevated levels of lipid peroxidation with a significant decrease in the levels of

superoxide dismutase and catalase in the testes of males and ovaries of female fishes indicating induced oxidative stress and marked histopathological was observed in pesticide and biotoxins treated fishes Table2 and Table 3.

Table 2: Reproductive endpoints of fishes exposed to biotoxins (mycotoxins and algal toxins).

Source	Name of The Biotoxin	Fish Species	Toxic Effect	Reference
Fungal	Aflatoxin B1 (AFB1) 20µg/kg bw	*Gibel Carp*	Decreased gonadal somatic index, Poor growth rate decreased fecundity, Decreased sperm count and motility	Haung *et al*., 2014; Jantrarotai *et al.*, 1990 A & B; Thamos, 1998
Fungal	Ochratoxin A (OTA) 187µg/kg bw	*Zebra fish*	Embryo toxicity, increased embryo mortality and oxidative stress	Tschirren *et al.*, 2018; Schwartz *et al*., 2010; Schwartz *et al*., 2013
Fungal	Zearalenone 1.2mg/kg	Several fishes	Estrogenic effects and affect on reproduction	Johns *et al*., 2009; Bakos *et al.*, 2013
Algae	Domoic acid (DA) 0.16-23.8 ng	*Danio rerio*	Embryo development is difficult	Tiedeken *et al.*, 2005
Algae	Saxitoxin (STX) 50-1600 µg/l	*Clupea harengus*	Embryo development is difficult	Lefebvre *et al.*, 2005
Algae	Brevetoxin (BTX) 1-8.5ng/l	*Oryzias latipes*	Embryo development is difficult	Colman and Ramsdell, 2003

Table 3: Reproductive end points of fishes exposed to pesticides.

Pesticide	Fish Species	Effect Of Pesticide	Reference
Dimethoate 1.6mg/kg bw for 6month	*Clarias batrachus*	Decreased fecundity, Decreased estradiol hormone	Begum and vijayaraghavan, 1995
Dimethoate and/or Malathin 0.17mg/kg bw for 120 days	*Nile tilapia*	Decreased spermatogenesis, decreased steroidogenesis and increased oxidative stress	Eman *et al.*, 2011
Cypermethrin 1mg/kg bw for 45 days	*Heteropnuetes fossilis*	Decreased sperm motility and concentration	Ghada, 2009; Musa, 2010
Chlorpyrifos 5, 10 and 15 ppb for 30 days	*Oreochromis niloticus*	Decreased testosterone and estradiol-17β	Ozcan Oruc, 2010

5. CONCLUSION

In the present study, the effect of pesticides and biotoxins alone or combination on the reproduction in male and female fish were studied. From the results, it is concluded that these toxicants deteriorate the reproductive ability of male and female fishes.

Exposure to mycotoxins and pesticides alone or in combination on fishes results in: Significant decrease in the weights of testes, a significant decrease in the sperm parameters like daily sperm production, epididymal sperm count, motile sperm, viable sperm, and the number of HOS tail coiled sperm and testis volume in all experimental fishes treated with pesticides. And also significantly diminish the activity levels of testicular steroidogenic hormones. Elevated levels of lipid peroxidation with a significant decrease in the levels of superoxide dismutase and catalase in the testes indicating induced oxidative stress and marked histopathological was observed in pesticide-treated fishes Table 3.

From the results, it can be concluded that exposure to pesticides together with mycotoxins further deteriorated the reproductive endpoints indicating additive effects of these chemicals because adult exposure revealed almost overall reproductive parameters like weights of reproductive organs, epididymal sperm quantity and quality, steroidogenic enzyme activities, circulatory levels of testosterone, histology of testis, lipid peroxidation levels and antioxidant enzyme activities are inflated by pesticides and biotoxins in male and female fishes.

6. FUTURE PERSPECTIVES

In nature, aquatic fishes are exposure to varieties of stresses simultaneously; hence there is an emergent need to re-establish safe levels of natural / anthropogenic chemicals in food stuffs and in water for determining the associated risk to marine, fresh water and brackish water animals and wild life.

7. ACKNOWLEDGEMENT

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8. DECLARATION OF CONFLICTING INTERESTS

The author declares that there is no conflict of interest of this scientific work.

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