RESEARCH PAPER

Environment

Volume : 4 | Issue : 5 | May 2014 | ISSN - 2249-555X

Toxicity of Pesticide Deltamethrin to Fish

KEYWORDS

deltamethrin, toxic, fish

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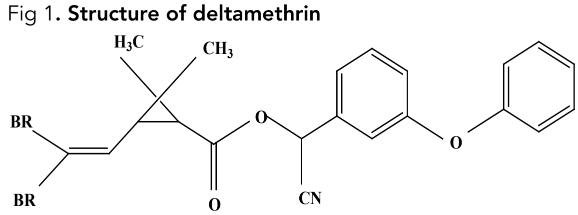
ABSTRACT *Deltamethrin is widely used and most effective pesticide based on pyrethroid preparations. It is extensively used in agriculture, for controlling pests, insects and vectors of endemic diseases, protecting seeds during storage and fighting household insects because of their low environmental persistence. However, deltamethrin is found to be highly toxic to various non-targeted aquatic organisms including fish. Contributing factor to the sensitivity of fish to deltamethrin exposure seems to be its high rate of gill absorption due to the lipophilicity. The main mode of its action is neurotoxicity, and its capacity to induce oxidative stress or alteration of antioxidant system and lipid peroxidation. Thus, the main aim of this study is to review the toxic effect of synthetic pyrethroid, deltametrin in fish.*

INTRODUCTION

Pesticides are the major potential environmental hazards to humans and animals as these are present and concentrated in the food chain. The long-term ecological hazards associated with the use of organochlorine, organophosphate and carbamate pesticides has led to the introduction of a new generation of pesticides with a lesser degree of persistence. In this direction, synthetic pyrethroids have emerged as a replacement. Synthetic pyrethroids are modified derivatives of pyrethrins, natural substances obtained from flowers of Pyrethrum species (Luty et al., 2000). One pyrethroid which is used more commonly than other synthetic pyrethroids and has found wide acceptability for agricultural purposes is deltamethrin (Haya, 1989). The technical grade deltamethrin is composed of eight stereomeric esters (four cis and four trans isomers) of the di-bromo analogue of chrysanthemic acid, 2,2-dimethyl-3 cyclopropanecarboxylic acids (Fig 1). Deltamethrin was synthesised in 1974, and first marketed in 1977 (Pham et al., 1984).They are extensively used in agriculture, for controlling pests, insects and vectors of endemic diseases, protecting seeds during storage and fighting household insects because of their low environmental persistence (Braguini et al., 2004). The extensive use of deltamethrin on land may be washed into surface water and can adversely influence or kill the life of aquatic organisms and other higher animals. Aquatic organisms, particularly fish, are highly sensitive to deltamethrin (Ural et al., 2005; Assis et al., 2009). Due to their lipophilicity, pyrethroids have a high rate of gill absorption, which would be a contributing factor in the sensitivity of the fish to aqueous pyrethroid exposures. Fish seem to be deficient in the enzyme system that hydrolyzes pyrethroids (Haya et al., 1989). It has been found that the fish exhibit several symptoms of stress when treated with deltamethrin (Datta et al., 2003). Emulsifiable concentrate formulations of pyrethroids are usually two to nine times more toxic than the technical grade, most likely due to synergistic interactions (Sanchez et al., 2005). subacute effects of pyrethroids to fish incorporate behavioural changes and tissue damage (Smith et al., 1986). Generally, deltamethrin affects the overall physiological profile in fish with particular reference to the energy metabolism, biochemical and haematological characteristics (El-Sayed et al., 2007). The mechanism of its neurotoxic effectiveness is the same as that of other type II pyrethroids: blockage of the sodium channels and inhibition of γ -aminobutyric acid receptors. Effects of deltamethrin on nervous, respiratory and haematological systems have been reported (Golow et al., 1994). Possible toxicological actions of the pyrethroids include disruption of calcium and phosphate homeostasis (Srivastav et al., 1997) and abnormalities in haematopoiesis and protein synthesis (Svobodova et al., 2003). Deltamethrin causes severe morphological alterations in the gills and liver and causes toxic effects on the haemobiotic organs, liver and gills (Yildirim et al., 2006). Deltamethrin may disturb the calcium and phosphate homeostasis and may lead to an effect on the reproductive state of the fish (Maund et al., 2002).

Fig 1**. Structure of deltamethrin**



COMMON NAME

Deltamethrin is commonly known by its trade name as Decis and Butox®.

ACUTE TOXICITY

Acute toxicity data for deltamethrin in fish have been summarized in a report of the World Health Organization (WHO, 1990) and classified as highly toxic to fish, the LC_{50} being in the < 1.0 ppb range (Datta et al., 2003) have concluded that deltamethrin is highly toxic to fish; even minute concentration (0.01 mgL^{-1}) of deltamethrin could cause 50% mortality of Clarias gariepinus in 24 hrs and is also highly toxic to Channa punctatus even in very low concentration (0.075mgL^{-1}) (Jayaprakash et al., 2013). LC_{50} values of deltamethrin on Nile tilapia (Oreochromis niloticus) larvae and fry after acute exposure to deltamethrin and the 48 h LC_{50} values for Nile tilapia larvae and fry were reported as 1.17 and 1.70 μg L^{-1}, respectively (Caglan et al., 2009).The acute semistatical toxicity test lasting 96 h was performed on rainbow trout juveniles. The 96h LC_{50} value of Decis (EC 50) was found to be 0.02 mg L^{-1} (Velisek et al., 2007). The 48 h LC_{50} and LC_{99} values of deltamethrin in P. reticulata was determined as 5.13 and 33.09 mg L^{-1}, respectively (Viran et al., 2003) while 96 h LC_{50} value for C. carpio as 0.058 mg L^{-1}. [14]. The LC_{50} value of deltamethrin to the freshwater fish, Puntius chrysopterus was found to be 0.0142 mg L^{-1} (Pawar et al., 2009).

NEUROTOXIC EFFECT

The neurotoxic effect of the synthetic pyrethroids, deltamethrin is attributed to the blocking of sodium channels and inhibiting the GABA receptors in the nervous filaments which results in an excessive stimulation of the central nervous system that sometimes can lead to brain hypoxia (El-Sayed et al. 2007).The changes in AChE activity and ACh content showed inhibition in the enzyme activity, followed by a concomitant increase of ACh content in all the tissues such as brain, kidney, liver, and muscle of males and females of Channa punctatus during deltamethrin exposure (Venkataramudu et al. 2008) while 70–90% decrease in acetylcholinesterase activity of brain, heart, blood, liver and skeletal muscle was found in carp after 5 days of deltamethrin exposure in concentration of 2 mgL^{-1} (Balint et al. 1995).The study demonstrated that deltamethrin caused ATPase inhibition in the gills and heart Na^+K^+-ATPase activity but did not show any inhibition in the ChE activity in muscle in A. multispinis after deltamethrin exposure (Helena et al., 2009).

BEHAVIOURAL CHANGES

In a study on young mirror carp (Cyprinus carpio), abnormal behavioral responses were observed on deltamethrin exposure (Pham et al., 1984). In another study, the exposure on guppies (Poecilus reticulata) to various concentrations of synthetic pyrethroids, deltamethrin resulted in less general activity, loss of equilibrium, hanging vertically in the water, rapid gill movement, erratic swimming, swimming and air gulping at the water surface (Amin et al., 2012). Fish exhibited several abnormal behavioural changes in the form of rapid operculum movement, swimming at the water surface and gasping from the water as a respiratory distress (El-Sayed et al., 2007). Behavioural changes exposed to lethal concentration of deltamethrin resulted in rapid and erratic swimming with random movements, toxic seizures, imbalance in posture, increase in surfacing activity and opercular movements and gradual loss in equilibrium. Appearance of mucous covering over the gills and the colour of the gill lamellae were found to be changed from red to brown (Pawar et al., 2009).

EFFECTS ON ANTIOXIDANT

It has been established that pyrethroids can induce oxidative stress/alteration of antioxidant system and lipid peroxidation and showed that lipid peroxidation in cells increased with pyrethroids treatment and antioxidant enzyme activities and malondialdehyde were altered after exposure to pesticides in fish (Akhtar et al., 1994) . Deltamethrin has an oxidative-stress-inducing potential in fish but reduced level of the catalase activity in liver, brain, kidney and gill were observed in Channna punctata exposed to deltamethrin (Sayeed et al., 2003). Also, in zebrafish, Danio rerio exposed to deltamethrin during 16-days exposure period on the antioxidant enzyme catalase (CAT), lipid peroxidation (LPO) and the reduced glutathione (GSH) of brain and muscle induced a distinct oxidative stress in the brain and muscle (Dilip et al., 2013).It has been found that deltamethrin produced oxidative stress in fish gill more than liver and kidney both at catalase activity and MDA levels and concluded that α-tocopherol could modulate and diminish the adverse effects of deltamethrin on most of biochemical parameters, lipid peroxidation and enzymatic activities if used in low concentration (12 μg L^{-1}) (Amin et al., 2012) The alterations in the activities of several antioxidant enzymes in the gills of the freshwater fish Carassius auratus gibelio exposed to deltamethrin resulted in an immediate adaptive response to the oxidative stress (Staicu et al., 2007).

HISTOPATHOLOGICAL CHANGES

Fish liver histopathology is an indicator of chemical toxicity and it is a useful way to study the effects of exposure of aquatic animals to toxins present in the aquatic environment (Fernandes et al., 2008). Fish gills can absorb even minute concentrations of the pyrethroids pesticide because of their lipophilic nature. In fish, gills are the critical organs for their respiratory, osmoregulatory and excretory functions. A high rate of absorption of deltamethrin through gills also makes fish a vulnerable target of its toxicity (Srivastav et al., 1997). As far as deltamethrin is considered, there is a lack of experimental results about the histopathological effects of deltamethrin in the literature. Severe histopathological effects of deltamethrin were observed on the gill and kidney in tissues of the common carp after acute exposure in concentration of 0.029 and 0.041 mg L^{-1} (Cengiz, 2006). A study was conducted on the histopathological effects of deltamethrin on the gill, liver and of the mosquitofish, Gambusia affinis, exposed to two sublethal concentrations of deltamethrin (0.25–0.50 g L^{-1}) for periods of 10, 20 and 30 days (Cengiz et al., 2007). In a study on the monosex Nile tilapia, Oreochromis niloticus L., exposed to sub-acute concentration (1.46μgL^{-1}) of a pyrethroid insecticide, deltamethrin for 28 consecutive days and the histopathological results indicated that the hemopoetic organs primarily liver and gills were affected by deltamethrin (El-Sayed et al., 2007). In a study on Carassius auratus gibelio exposed for 1, 2, 3, 7 and respectively 14 days to deltamethrin 2μg/L induced hepatic, gonadal and renal toxicity (Staicu et al., 2007).

HAEMATOLOGICAL CHANGES

Haematological indices are very important parameters in evaluating the physiological status of the fish. In a study, Jayaprakash et al. (2013) evaluated the changes in some hematological parameters of the fresh water fish Channa punctatus exposed to lower (0.075 mgL^{-1}) and higher (0.15 mgL^{-1}) sub lethal concentrations of LC50 (0.75mgL^{-1}) of the synthetic pyrethroid pesticide deltamethrin for 15, 30 and 45 days. Fish exposed to both the concentrations for 45 days showed a significant decrease in the hemoglobin content, total erythrocyte count, packed cell volume, mean corpuscular volume, mean corpuscular hemoglobin concentration, as compared to the respective control fish. while, there was a significant increase in the total leukocyte count, mean corpuscular volume, erythrocyte sedimentation rate, and clotting time values during 30 and 45 days of exposure in lower and higher concentrations of deltamethrin. The differential leukocyte count in fish of 30 and 45 day test period showed a significant increase in the populations of lymphocytes, neutrophils and eosinophils, and significant decrease in monocyte and basophil populations. There was significant reduction in the mean length, breadth and area of erythrocytes in these deltamethrin exposed fish. Thus, the study revealed that the synthetic pyrethroid pesticide deltamethrin adversely affects the hematology of the freshwater fish Channa punctata. The main haematological response of carp to the acute effect of the deltamethrin-based preparation at a 0.13 mgL^{-1} concentration was a significant decrease in erythrocyte count, haematocrit, haemoglobin content and total protein content in blood plasma as compared to the control group (Svobodova et al., 2003). In freshwater catfish, Heteropneustes fossilis, the Hb (%) decreased after 30 days exposure to deltamethrin (Sayeed. et al.2003). In a study, Pimpao et al. (2007) observed an increase in the total erythrocyte counts in catfish (Ancistrus multispinis) intoxicated with deltamethrin, while, El-Sayed et al. (2007) observed a significant increase in erythrocytes, hemoglobin and hematocrit rate in Nile tilapia (Oreochromys niloticus) exposed to this same toxic substance.

BIOCHEMICAL PROFILES

The activities of plasma enzymes (ALT, AST, LDH and CK) are also used as a indicator of deltamethrin stress. In a study, Velısek et al. (2006) showed a significant increase ($p < 0.05$) in AST and ALT levels in carp after acute exposure to deltamethrin in concentration of 3.25μgL^{-1}. (Helena et al. (2009) observed an increase of lactate dehydrogenase and glucose in common carp (Cyprinus carpio) after exposure to deltamethrin. Furthermore, the work done by El-Sayed et al. (2007) showed that deltamethrin significantly elevated serum AST and ALT enzyme activities at all weeks in relation to control values in Oreochromis niloticus and the values of glucose and cholesterol were found to be significantly increased in all fish exposed to the toxicant when compared to the control. The main biochemical response of rainbow trout to the acute effect of deltamethrin-based preparation was found to significantly decrease in plasma glucose, alanine aminotransferase, cholinesterase where as a significant increase were found in plasma total protein, albumins, ammonia, aspartate aminotransferase, creatine kinase and calcium compared to

Volume : 4 | Issue : 5 | May 2014 | ISSN - 2249-555X

the control group (Velisek et al., 2007). In another study, the glycogen levels were found to be depleted in all the tissues after deltamethrin exposure to sublethal concentration over the control. Maximum decrease in glycogen content was observed in kidney followed by brain, gill, muscle, liver, testis and ovary (Pawar et al., 2009).

ENZYMATIC ACTIVITY

Few studies have also been reviewed that investigate the effect of deltamethrin on digestive enzymes of fish. Simon et al. (1999) examined the effects of deltamethrin, on the digestion enzymes of carp, Cyprinus carpio. Another study revealed that the various concentrations of deltamethrin inhibited the lipase activity in Poecilia reticulata and significant decrease of lipase activity was also observed as the concentration of deltamethrin increased (Gunes et al., 2011).

IMMUNE SYSTEM

The influence of deltamethrin on the innate immunity in rainbow trout was examined and showed that deltamethrin at doses of 2 and 4 µg/L decreased phagocytic activity of spleen macrophages and proliferative response of pronephros lymphocytes at days 1, 2, and 5 after immersion and decreased lysozyme activity, total protein, and immunoglobulin levels in serum has been observed (Siwicki et al., 2010).

CONCLUSION

Several workers have studied on deltamethrin toxicity in fishes and showed that it causes varied effect including histopathological, oxidative stress, haematological, neurotoxic, biochemical changes as well as immunological effects. Also, deltamethrin has found to be highly toxic in fishes even in very low concentration. Therefore, it is suggested that the use of these types of pyrethroid pesticides should be judicious and controlled so as to control agriculture pests.

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