Plasma proteins, hepatic enzymes, thyroid hormones and liver histopathology of *Cyprinus carpio* (Linnaeus, 1758) exposed to an oxadiazin pesticide, indoxacarb

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**Abstract**

Indoxacarb is a relatively new pesticide from oxadiazin class, which is used near carp ponds for agricultural purposes. Thus, the aim of this study was to determine indoxacarb effects on common carp (*Cyprinus carpio*). The fish were exposed to 0 (control), 0.75, 1.5 and 3 ppm of indoxacarb over 21 days and plasma biochemical characteristics and liver histopathology were examined. Exposure to indoxacarb induced fall in total protein after 21 days. Globulin increased after 7 days and then decreased after 14- and 21-day exposure. Plasma alanine transaminase and aspartate transaminase activities increased in 1.5 and 3 ppm treatments after 7-day exposure. Indoxacarb exposure significantly decreased plasma alkaline phosphatase after 7 days with no change at the second and third samplings. After 7 days, plasma T3 levels had no significant change; however, it decreased after 14 days in the 1.5 and 3 ppm treatments and also reduced after 21-day exposure to the 3 ppm treatment compared to the control group. Plasma T4 level only decreased significantly in the 3 ppm treatment compared to the control group after 21 days. Different histopathological symptoms such as necrosis, hyperaemia, sinusoidal space extension, pyknotic nuclei, leucocyte infiltration and melanomacrophage aggregates were observed after 21-day exposure to indoxacarb. The symptoms intensity was dependent on indoxacarb concentration. In conclusion, the present results show that indoxacarb exposure adversely affects common carp health and welfare, which consequently may induce serious problems in this species aquaculture.

**KEYWORDS**

common carp, hepatic enzymes, indoxacarb, liver histopathology, plasma proteins, thyroid hormones

**1 | INTRODUCTION**

Environmental pollution has become one of the most important problems in the world (Chandran, Sivakumar, Mohandass & Aruchami, 2005; Saghali, Hoseini, Hosseini & Baqraf, 2014), and pesticide contamination of aquatic system has attracted the attention of researchers (Dutta & Dalal, 2008). The use of pesticides has increased in the last decades due to extensive use in agricultural processes that are becoming threats to living organisms. Fish are more frequently exposed to these pollutants as non-target organisms; because the pollutant may go into the aquatic environment (Saghali et al., 2014).

The aquaculture industry is threatened by natural water pollution. Natural waters are used to fill fish ponds and tanks. Therefore,
water contamination causes fish toxicity and consequently economic loss. In the northern part of Iran, aquaculture is still considered as important activity as agriculture, and thus, many fish ponds are located near the agricultural area. *Cyprinus carpio* is one of the most important species in aquaculture systems of the north of Iran. Tobacco and cotton are two main crops, which are farmed extensively in the northern area of Iran, and their pests were treated with different pesticides namely carbamate, organophosphate, organochlorine and indoxacarb (Malekzadeh & Javadzadeh, 2002; Mohaghegh Naishabouri, Rostamkolaiz Motlagh & Goodarzian, 2009). Indoxacarb is a new pesticide of oxadiazin class, which is used to control sucking pests of crops, especially acts against lepidopteran larvae (Moncada, 2003). Available data show that indoxacarb blocks the flow of sodium ions into nerve cells of pests by binding to a site on sodium channels (Brugger, 1997), but this mechanism has not proven in fish.

As blood is a pathophysiological indicator of the whole body, blood parameters are important in detecting the fundamental status of fish exposed to toxicants (Adhikari, Sarkar, Chatterjee, Mahapatra & Ayyappan, 2004). Study on blood biochemical changes indicates alterations in metabolism and biochemical processes of the organism, which resulting from the effects of various toxicants. And in this way, it is possible to study the mechanisms of the effects of these toxicants (Luska, Svoboda & Kolárová, 2002). Previous studies have shown that pesticides can cause either increase or decrease in levels of plasma protein, activities of plasma enzymes and thyroid hormones depending on the toxicant type, species of fish, water quality and length of exposure (Jee, Masroor & Kang, 2005; Monteiro, Manzera, Fontainhas-Fernandes & Sousa, 2005).

Fish liver injury is another physiological disturbance, which is occurred in pesticides exposure (Adel et al., 2016; Boran, Altinok & Capkin, 2010; Capkin, Terzi, Boran, Yandi & Altinok, 2010; Da Cuna et al., 2011; Figueiredo-Fernandes et al., 2007). Liver is the main organ of various fundamental metabolic pathways. Also it is the primary organ, which is adversely affected by chemicals. This, in turn provides important data on the chemical’s toxicity and mode of action. Many organic compounds induce toxicopathic lesions in the liver of fish species.

According to above, toxicants’ exposure negatively affect fish health and well-being, thus threatens aquaculture production. Therefore, it is of interest to consider the toxicants effects on aquaculture species. There are no adequate studies about the effect of indoxacarb on fish. According to Taheri Mirghaedi and Ghelichpour (2015), The acute toxicity of indoxacarb was measured in two temperature and indoxacarb determined as “harmful” pesticide in *C. carpio* and causing behavioural alterations and mortality. The biochemical parameters of Indian major carp *Labeo rohita* exposed to lethal and sublethal concentrations of indoxacarb investigated by Veeraiah, Rao and Dhilieswarao (2013). Results showed indoxacarb is highly toxic to fish with 96 hr LC50 of 0.053 ppm. Also, decrease in protein, glycogen and nucleic acids content in different organs was reported in those exposed fish. Seemingly, scarce data are available on the effects on this pesticide on fish, and no data on *C. carpio*. Thus, the aim of this study was to investigate the effects of indoxacarb exposure on plasma biochemical and liver histopathology in common carp.

## 2 MATERIALS AND METHODS

### 2.1 Maintenance conditions

Twelve fibreglass tanks (300 L in volume, filled with 160 L water) were stocked with common carp (~45 g in weight) with the stocking density of 28 fish per tank. The fish were fed with commercial carp feed (Mazandaran Animal & Aquatic Feed Co., Sari, Mazandaran, Iran) once a day (1.5% body weight) over 7 days under continuous aeration condition. During this acclimation period, daily water exchange, temperature, dissolved oxygen, electro-conductivity, salinity, pH, total hardness, alkalinity and calcium were 75%, 23 ± 1.27°C, 7.14 ± 0.84 mg/L, 4630 ± 55 μs/cm, 2.63 ± 0.15 g/L, 8.07 ± 0.25, 300 ± 17.5 mg/L (as CaCO3), 350 ± 20.3 mg/L (as CaCO3), 110 ± 11.7 mg/L respectively.

### 2.2 Indoxacarb exposure and sampling

After acclimation, each three tanks were considered as a treatment (a total of four treatments): control (without indoxacarb), 5% of 96-hr-LC50 (0.75 ppm), 10% of 96-hr-LC50 (1.5 ppm) and 20% of 96-hr-LC50 (3 ppm). Indoxacarb (purity = 15%) was produced by Hef Iran Co. (Tehran, Iran). Feeding was performed same as the acclimation period. The tanks’ water was replaced (75%) by freshwater every day, and required amounts of indoxacarb were added to each tank. The fish were bled (six samples per treatment) in each sampling time: 7, 14 and 21 days after exposure to indoxacarb. The fish were not fed for 24 hr prior to blood sampling. Blood samples were obtained from caudal vein, using heparinized syringes. Plasma was separated after 10 min centrifugation (1,000 g), and well-preserved at −80°C until analysis. Plasma levels of total protein, albumin, globulin; aspartate transaminase (AST), alanine transaminase (ALT) and alkaline phosphatase (ALP); and T3, and T4 were determined. Liver tissue samples were taken from all treatments after 21-day exposure to indoxacarb (two fish per tank).

### 2.3 Analysis

Water temperature, dissolved oxygen, electro-conductivity, salinity and pH were measured daily during the experiment by Hach HQ40d portable apparatus (Loveland, Colorado, USA). Total hardness, alkalinity and calcium were determined using photometer (Wagtech 7100, Berkshire, UK). Plasma total protein, albumin, globulin levels, AST, ALT and ALP activities were determined spectrophotometrically using Pars Azmun kits (Pars Azmun Co., Tehran, Iran). Plasma T3 and T4 levels were determined by ELISA kits provided by Pishhtaz Teb Co. (Tehran, Iran). The liver samples were fixed in buffered formalin (10%) for further sectioning and histopathological analysis. The tissues were then processed, paraffinized, sectioned (5 μm thickness) and stained (haematoxylin and eosin) for histological examinations.
and prepared for light microscopy analysis (Haschek, Wallig & Rousseaux, 2010).

2.4 Statistical analysis

After normality confirmation (Shapiro–Wilk test), data of each sampling time were analysed separately, as there was no significant difference in the control data at different sampling time. The plasma data were subjected to one-way ANOVA (indoxacarb concentration). Significant differences among the treatments were delineated by Duncan’s test ($p < .05$). Data were presented as mean ± SD. All analyses were performed using SPSS software (v.22). The incidence of tissue injuries was reported on a semi-quantitative scale scored with three categories according to the intensity of alterations: none (−), mild (+), moderate (++) and severe (+++) according to Di Giulio and Hinton (2008).

3 RESULTS

3.1 Plasma proteins

Plasma total protein of different treatments (0.75, 1.5 and 3 ppm) had no significant differences compared with control group in spite of some fluctuations during 7 days. However, the 3 ppm treatment had the highest total protein concentration among the treatments. Plasma total protein of different treatments decreased after 14 days but the decrement was not statistically significant. There was a significant reduction in total protein levels of the fish exposed to indoxacarb treatments after 21 days (Figure 1). No significant changes in plasma albumin levels were observed among different treatments at any sampling times (Figure 2). Figure 3 illustrates that plasma globulin levels of 3 ppm treatment were significantly higher than that in the control group; however, 0.75 and 1.5 ppm treatments had no
significant differences with the control group during 7 days. In the second and third sampling times (14th and 21st days), indoxacarb treatments showed a significant decrease in globulin levels of plasma compared to the control group.

3.2 \(\text{ Plasma hepatic enzymes activity }\)

Changes in plasma AST and ALT activities are shown in Figures 4 and 5. The trends of these two hepatic function indicators are similar. After 7 days, plasma AST and ALT activities of \textit{C. carpio} increased significantly in the 1.5 and 3 ppm treatments. However, plasma AST activity of the indoxacarb treatments had no significant changes compared to the control group after 14 and 21 days. Plasma ALP activity in the indoxacarb treatments was lower than that of the control group after 7-day exposure. The results showed no significant changes of plasma ALP activity in different treatments at 14th and 21st days (Figure 6).

3.3 \(\text{ Plasma thyroid hormones }\)

Figure 7 shows that there were no significant changes in the \(T_3\) levels of plasma among different treatments during 7 days. After 14 days, \(T_3\) levels decreased in the 1.5 and 3 ppm treatments. However, after 21 days, a significant reduction was observed in 3 ppm treatment compared to the control group.

The results of plasma \(T_4\) showed no significant changes among the different treatments at the first and second sampling time (after 7 and 14 days). After 21-day exposure, plasma \(T_4\) in the 3 ppm treatment was lower than the control group. However, 0.75 and 1.5 ppm treatments had no significant decrease (Figure 8).

3.4 \(\text{ Histopathological injuries of liver }\)

No pathological symptoms were observed in the control group (Table 1 and Figure 9). The results of the histopathological symptoms...
in the indoxacarb-treated fish are presented in Table 1, Figures 10–12. Necrosis hyperaemia, sinusoidal space extension, pyknotic nuclei, leucocyte infiltration and melanomacrophage centres are different histopathological symptoms of the liver in three indoxacarb treatments. Necrosis, hyperaemia, sinusoidal space extension and pyknotic nuclei intensities were depended on indoxacarb concentration. Leucocyte infiltration was only observed in the 3 ppm treatment, and melanomacrophage aggregates incidence in the 1.5 ppm treatment was higher than the other treatments.

4 | DISCUSSION

Physiological pathways of aquatic animals are affected by water pollution, so that, the study of the physiological response of the animals to toxicants provides useful information about the potential toxicity and intoxication mechanisms. Indoxacarb brings out several behavioural and physiological alterations upon entering into the fish body (Taheri Mirghaed & Ghelichpour, 2015; Veeraiah et al., 2013). Blood is one of the best indicators of toxic substances’ stress and analysis of biochemical blood parameters of fish are extensively used to consider the toxic substances’ stress and status of the animal health (Kavitha, Malarvizhi, Kumaran & Ramesh, 2010).

4.1 | Plasma proteins

Fish plasma protein is an important compound with several roles such as transporting the other compounds, immune function and control of the osmotic pressure. Also, proteins are important biochemical indicators, which are used to recognize the fish health, physiology and metabolism under pesticides intoxication (Clark & Holling, 1931; Corbel, 1975; Hoseini & Tarkhani, 2013; Silva,
Cortez-Moreira, Bastos, Bastos & Cortez, 2010). Total protein, albumin and globulin tests are used to monitor each disorder in the immune system and dysfunction of liver and kidney (Banaee, Mirvaghefei, Rafei & Amiri, 2008; John, 2007). In the present study, three concentrations of indoxacarb caused significant decrease in plasma total protein level at the third sampling (after 21 days) compared to the control group, and significant reduction in globulin after 14 and 21 days. However, plasma globulin level increased at 3 ppm treatment of indoxacarb after 7 days. The levels of plasma proteins might change as a result of haemoconcentration, haemodilution, stress response and change in protein synthesis of the liver (Hoseini & Tar-khani, 2013). As the levels of albumin had no significant changes during the indoxacarb exposure in this study, it is hypothesized that no haemodilution happened in the indoxacarb-treated fish. Therefore, the reduction in total protein and globulin could be as a result of a change in liver protein synthesis due to the indoxacarb treatment. Overall, total protein levels may decrease due to malnourishment and chronic liver disease. Liver is one of the main target organs for the accumulation of pesticides. As the metabolic potential is oriented towards liver, and it is the site for the synthesis of various proteins and the regulating centre of metabolism, hepatocyte damages could be the main reason for protein changes. Other investigations also show a decrease in total protein levels of fish exposed to different pesticides (Banaee et al., 2008; Velisek, Svo-bodova & Machova, 2009; Vijayan, Feist, Otto, Schreck & Moon, 1997). Veeraiah et al. (2013) reported reduction of protein content in different tissues (liver, gill, brain, kidney, intestine, muscle) of Labeo rohita exposed to sublethal concentrations of indoxacarb. They noticed that protein content reduction in the most of the fish tissues may be due to the leading of free amino acids for the synthesis of necessary proteins, or synthesis of glucose in gluconeogenesis pathway by metabolic utilization of the keto acids, or even for the maintenance of osmotic and ionic regulation (Veeraiah et al., 2013).
Some kinds of globulins are immune-related proteins namely lysozyme, immunoglobulins and complement proteins that might either decrease (Yin, Lam & Sin, 1995) or increase (Caipang, Berg, Brinchmann & Kiron, 2009) under stressful condition. The decrease in globulin level had been reported in some studies as a result of immune deficiency due to various pesticides exposure as an immunosupressant (Banaee et al., 2008; Girón-Pérez et al., 2007). Increase in plasma globulin level after 7 days might be as a result of an increase in some enzymes (e.g. ALT and AST, discussed below) and protective proteins (e.g., HSP family and antioxidants) to contract adverse effects of the toxicity (Hoseini & Tarkhani, 2013).

Further, kidney disorder may cause the excretion of protein instead of retaining it in the blood, and it may cause depletion in the blood protein levels (Sastry & Sharma, 1981). Eventually, protein synthesis, and liver and kidney function of fish might be affected by prolonged and sublethal pesticides exposure (Saravanan, Kumar & Ramesh, 2011).

4.2 Plasma hepatic enzymes

Alanine transaminase and aspartate transaminase are found in the most fish organs; heart, skeletal muscle (Petrović, Ozretić & Kranjović-Ozretić, 1996), kidney, pancreas, spleen, erythrocyte, brain and gills (Bhattacharya, Xiao & Lun, 2008) and at high concentration in liver (Srivastava et al., 2004) specially in common carp; also, the amount of AST in common carp kidney is more than ALT (De Smet & Blust, 2001). In general, the injuries of the tissues cause cell destruction and transudation of these enzymes into blood circulation (Hoseini, Rajabisterabadi & Kordostami, 2016). Increased plasma ALT activity in the indoxacarb-treated fish after 7 days suggests liver injuries, which is supported by histopathological data (reported below). The results showed that plasma AST levels increased compared to the control group after 7-day exposure to indoxacarb as well as ALT. As AST is not a specific hepatic enzyme, this elevation might be as a result of other fish organs’ injury beside the liver. The plasma ALT and AST activity indicated the liver impairment occurred in all indoxacarb-exposed fish, and the damage was probably depended on the dose of indoxacarb. Increased activity of AST and ALT observed in different fish species which exposed to various toxicants (Agrahari, Pandey & Gopal, 2007; Banaee et al., 2008; Hoseini, Hosseini & Soudagar, 2012; Hoseini & Tarkhani, 2013). In the present study, plasma ALT and AST showed elevation only at the first sampling time, despite the hepatic damages at the third sampling time. This contradictory may be related to suppressed enzymes’ production by hepatocyte parallel to indoxacarb exposure. Therefore, there was not much enzyme in the liver to be leaked into circulation due to hepatocyte damage.

Liver can produce another enzyme named ALP via the cells lining the small bile; whereas, this enzyme is found in different body tissues in addition to liver (Agrahari & Gopal, 2009). Toxicants may increase (Hoseini, Hedayati, Mirghaed & Ghelichpour, 2016; Hoseini & Tarkhani, 2013; Karan, Vitorović, Tutundzić & Poleksić, 1998) plasma ALP activity. It was suggested that plasma ALP elevation could be related to tissue damage, especially, when the hepatobiliary problems occur; however, its demotion might be due to an impairment of the membrane transport system (Bernet, Schmidt, Wahl & Burkhardt-Holm, 2001; Haschek et al., 2010).

4.3 Plasma thyroid hormones

Pesticides usually cause endocrine disruption of the hypothalamic–pituitary–thyroid axis (HPT axis) (Tian, Li, Wang, Wu & Ru, 2012; Tian, Ru, Bing & Wang, 2010). The changes in endocrine systems are not probably to be limited to the disruption of one axis, but they can also have significant effects on the other axis especially thyroid hormones (THs) (Zaccaroni et al., 2009). Indoxacarb as an oxadiazin pesticide might have this effect. The findings of the present study showed no changes in plasma $T_3$ levels of exposed fish after 7 days. Similarly, increasing trend of $T_4$ plasma levels of treated fish in accordance with indoxacarb-dose elevation was not significant during this time. The result could refer to no significant effect of indoxacarb on thyroid gland activity or on the way of thyroid hormones synthesis during this time. At the second sampling time, the results showed $T_3$ decreased significantly; however, $T_4$ had no changes. Finding the reason of this result needs notice on the complicated

![FIGURE 9](https://wileyonlinelibrary.com)
**FIGURE 10** Histopathology of liver in 1.5 ppm treatment showing necrosis (N), hyperaemia (H), sinusoidal space extension (S), melanomacrophage aggregates (M) and pyknotic nuclei (P) [Colour figure can be viewed at wileyonlinelibrary.com]

**FIGURE 11** Histopathology of liver in 3 ppm treatment showing necrosis (N), hyperaemia (H), sinusoidal space extension (S), melanomacrophage aggregates (M), pyknotic nuclei (P) and leucocyte infiltration (L) [Colour figure can be viewed at wileyonlinelibrary.com]

**FIGURE 12** Histopathology of liver in 0.75 ppm treatment showing necrosis (N), hyperaemia (H), sinusoidal space extension (S) and pyknotic nuclei (P) [Colour figure can be viewed at wileyonlinelibrary.com]
pathway of thyroid hormones. HPT axis controls primarily the thyroid endocrine system, via regulating THs dynamics by coordinating their synthesis, secretion, transport and metabolism (Carr & Patiño, 2011). Fish thyroid follicular cells synthesize mostly thyroxin (T₄), which is stimulated by thyroid-stimulating hormone (TSH) (De Groef, Van der Geyten, Darras & Kühn, 2006). In fish as well as other vertebrates, the amount of plasma T₃ (more activated form of thyroid hormones) concentrations is produced by peripheral enzymatic deiodination of T₄ in extra-thyroidal tissues such as liver (Van der Geyten, Mol, Puymers, Kühn & Darras, 1998), and circulating T₃ is mainly occurred in the liver (Orozco & Valverde-R, 2005). Subsequently, depletion in T₃ plasma levels is generally due to the decrease in T₄ production and/or secretion, or even it can be as a result of alteration in peripheral the thyroid hormones metabolism (Li, Xie & Zhang, 2008). As the depletion of T₃ levels is synchronized with relatively stable of T₄ in this study, possible changes in peripheral deiodination or metabolism of thyroid hormone or liver damages are suggested. Previous studies support our findings (Zhang, Tian, Wang & Ru, 2013). The mechanism of thyroid hormone biotransformation in extra-thyroidal tissues is mainly affected by iodothyronine deiodinases. According to importance of thyroid hormones in fish physiological stability, investigation about the impact of agricultural pesticides upon deiodinase activity and its response to hypo- and hyper-thyroidism at the enzyme activity seems necessary (Adams, Cyr & Eales, 2000; Brown et al., 2004; Coimbra, Reis-Henriques & Darras, 2005; Van der Geyten, Byamungu, Reynolds, Kühn & Darras, 2005; Van der Geyten et al., 2001). Some studies have indicated that deiodinase mRNA levels, at least in fish, might also be delicate to several environmental toxicants specially pesticides (Li, Zha, Li & Wang, 2009; Li, Zha, Yang, Li & Wang, 2011; Picard-Aitken, Fournier, Pariseau, Marcogliese & Cyr, 2007; Yu et al., 2010). After 21 days, plasma T₃ and T₄ levels in the indoxacarb-treated fish reduced at the 3 ppm treatment. The reduction of T₄ might be related to disorder in thyroid gland function or/and disruption in the pituitary gland and TSH activity.

4.4 | Histopathological injuries of liver

Fish pathological alterations are powerful indicators of exposure to environmental contaminations and to determine cellular change that may occur in vital organs (Dutta, 1996). The liver is the primary organ for, detoxification and excretion of harmful substances, and metabolism (Metcalfe, 1998; Yildirim et al., 2006).

Generally, environmental contamination in aquatic ecosystems is usually at a low level but chronic in the aquatic animals ( Morris & Protasowicki, 1990). Various histological injuries in tissues of fish might occur when they are exposed to sublethal concentration of pesticides or other chemical pollutants in their environment (Altinok & Capkin, 2007). In the present study, 21-day exposure of common carp to indoxacarb resulted in structural alterations of necrosis, hyperaemia, sinusoidal space extension, pyknotic nuclei, leucocyte infiltration and melanomacrophage aggregates. There is no research about the histopathological effect of indoxacarb in different tissues of fish, although many pesticides have been studied in this topic. Some researchers have been reported various fish hepatic injuries of different pesticides. Capkin et al. (2010) described the impact of three pesticides; carbosulfan, propineb and benomyl on the liver of rainbow trout (Oncorhynchus mykiss) and expressed that liver cell necrosis, an increase of sinusoidal space, intracellular oedema, lipid infiltration and pyknotic nucleus. Xing et al. (2012) showed that chlorpyrifos and atrazine induced different levels of hydropic degeneration, vacuolization, pyknotic nuclei and fatty infiltration in the liver of exposed common carp. Benli and Özkul (2010) reported that chronic exposure to sublethal fenitrothion concentrations caused cloudy swelling, hydropic degenerations and lipid infiltration. Hoseini, Hedayati, et al. (2016) indicated hepatocyte vacuolization and necrosis, leucocyte infiltration, melanomacrophage aggregates, hyperaemia and pyknotic nuclei in common carp exposed to copper.

In the present study, dominant histological injuries in the liver were necrosis, hyperaemia, sinusoidal space extension, pyknotic nuclei. As mentioned above, with the increase in indoxacarb concentration, the hepatic impairments rise. The elevation of plasma hepatic enzymes levels (especially ALT) as sensitive indicators of liver health in indoxacarb-exposed fish corroborate hepatic histopathological complications. Hepatocyte necrosis is the main reason for releasing the enzymes from the cytoplasm of hepatocytes to the blood circulation. Totally, incidence of necrosis, hyperaemia, sinusoidal space extension, pyknotic nuclei, leucocyte infiltration and melanomacrophage aggregates in the liver suggest hepatocyte death and recycling of the materials derived from cell death in the indoxacarb-exposed fish (Hoseini, Hedayati, et al. 2016).

5 | CONCLUSION

In conclusion, the present results show that indoxacarb exposure causes histopathological damages to common carp liver, which causes a decrease in protein synthesis, T₃ production and elevation in plasma enzyme activity. Also, indoxacarb causes impaired thyroid function and a decrease in T₄ synthesis. Such adverse effects may seriously threaten carp aquaculture as indoxacarb is intensively used around carp ponds.

REFERENCES


Li, W., Zha, J., Li, Z., Yang, L., & Wang, Z. (2009). Effects of exposure to acetochlor on the expression of thyroid hormone related genes in larval and adult rare minnow (Gobio crypsis rarus). Aquatic Toxicology, 94, 87–93.


Van der Geyten, S., Mol, K., Plymers, W., Kühn, E., & Darras, V. (1998). Changes in plasma T3 during fasting/refeeding in tilapia (Oreochromis niloticus) are mainly regulated through changes in hemat type II Iodothyronine deiodinase. Fish Physiology and Biochemistry, 19, 135–143.


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