EFFECT OF CARBARYL ON SOME BIOCHEMICAL CONSTITUENTS OF THE BLOOD AND LIVER OF *CLARIAS BATRACHUS*, A FRESH-WATER TELEOST

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(Received January 8, 1999 ; Accepted May 14, 1999)

ABSTRACT — Carbaryl, a carbamate pesticide, (LC₅₀ 15.08 mg/l for 96 hr, i. e. lethal concentration with 50% mortality) induced perturbations in the levels of certain biochemical components including the activities of some enzymes in the blood and liver of the fresh-water catfish, *Clarias batrachus* exposed to sublethal concentrations (1, 2 and 4 mg/l) of the pesticide for 96 hr and 15 days. The pesticide caused a decrease in the levels of total protein and glucose with a concomitant increase in the levels of inorganic phosphate and lactic acid in fish serum. However, very little change was recorded in the serum cholesterol level. The treatment of the fish with carbaryl led to a marked increase in the activities of transaminases (GOT and GPT), phosphatases (acid and alkaline) and lactate dehydrogenase in the fish serum, the magnitude of the effect being dependent on the pesticide concentration and duration of exposure. The increase in lactic acid concentration with subsequent decrease in glucose concentration indicates an enhanced rate of glycolysis due to pesticide stress. Furthermore, the significant decrease in the activity of fish liver succinate dehydrogenase suggests that anaerobic metabolism was favored over aerobic oxidation of glucose through Kreb's cycle in order to mitigate the energy crisis for survival. The rise in the activities of transaminases and acid phosphatase due to pesticide intoxication suggest enhanced protein catabolism and probable hepatocellular damage in the organism.

KEY WORDS: *Clarias batrachus*, Carbaryl, Carbamate pesticide, Protein metabolism, Enzymes

INTRODUCTION

Paddy fields and low land areas in Northeastern India are natural habitats of the air-breathing catfish, *Clarias batrachus* (Linn.). It is an edible fish found in ponds, lakes and rivers in India. It possesses four pairs of barbels which are sensitive to pH, salinity and temperature of the medium. The presence of paired barbels around the mouth makes its appearance like that of a cat. It is therefore called a catfish. With the accepted use of pesticides in agriculture, their effects on the overall growth, metabolism and reproduction of fish cannot be ruled out. Although the toxic actions of pesticides such as organocarbamates on the target pests and also on some terrestrial populations have been evaluated and studied extensively, their effects on non-target

animals such as fish await detailed investigations. The choice of the fish species for study is only due to its production potential from paddy fields and stagnant shallow ponds (Mukhopadhyay *et al.*, 1982).

The hazards of pesticides to fish are of great concern. In recent years, incidences of fish mortality due to industrial effluents, sewage pollution and pesticides have been reported (Mowdesley Thomas, 1971). Pesticides have been found to be highly toxic not only to fishes but also to fish-food organisms. A number of reports have appeared in recent years on the uptake and tissue distribution of pesticides in various fishes (Kaundilya and Ramamurti, 1980). Therefore, it is important to examine the toxic effects of pesticides on fish as they form an important part of human food.

Carbaryl (α -naphthyl 1-methyl carbamate), a car-

bamate pesticide, has a wide range of applications in agriculture as an effective systemic pesticide. The carbaryl-induced inhibition of enzyme activity and its additional biochemical effects have not been studied in much detail, particularly in commercially important food fish. However, Sastry and Siddiqui (1982) have reported that the carbamate, sevin, induced hyperlactemia as well as changes in the activities of some key enzymes of carbohydrate metabolism in different body tissues and blood of *Channa punctatus*, a snake-head fish.

The air-breathing catfish used in the present study, *C. batrachus*, is considered as one of the most suitable species for breeding and rearing in paddy fields because of its physiological and behavioral adaptations.

Earlier reports from this laboratory have shown that subacute concentrations of carbaryl induced drastic alterations in the level of biogenic amines in different parts of the brain of *C. batrachus* (Sharma *et al.*, 1993b) and adversely affected fish behavior. Also, this pesticide at sublethal concentrations has been shown to cause perturbations in the activities of acetylcholinesterase (Sharma *et al.*, 1993a) as well as lactate dehydrogenase (Sharma and Gopal, 1995) in the key organs of *C. batrachus* exposed to the pesticide. However, scanty reports are available concerning the effect of organocarbamate pesticides on the biochemical composition of fish serum. The present communication deals with the effect of carbaryl on some biochemical components of serum and liver of *C. batrachus* exposed to subacute concentrations of carbaryl for two different incubation periods, i. e. 96 hr and 15 days.

MATERIALS AND METHODS

Carbaryl (technical grade, 99% purity) in a crystalline form was obtained as a gift from Rallis India Ltd.-India. Potassium permanganate, acetone and all other reagents of high purity used for assays of some biomolecules including activities of certain key enzymes were procured from Sisco Research Laboratories Pvt. Ltd., India.

The healthy and alive fresh water teleost, *C. batrachus* (length 15-20 cm, weight 20-30 g) was obtained from a local fish market and brought to the laboratory in 20 liter plastic containers. The healthy fish were selected and treated with potassium permanganate solution (0.5%, w/v) for 5 min to remove any dermal adherent. The fish (90 Nos.) were acclimated for seven days in a rectangular aquarium (50 l) containing tap water at room temperature ($26 \pm 2^\circ\text{C}$) with food

ad libitum under standard laboratory conditions. The LC_{50} value of carbaryl (technical grade, purity 99% and dissolved in acetone) for *C. batrachus* has already been determined in our laboratory (15.08 mg/l for 96 hr) (Sharma *et al.*, 1993b). The fish were equally divided into six groups; three of them were exposed to sublethal concentrations of carbaryl (1.0, 2.0 and 4.0 mg/l) for two different exposure periods of 96 hr and 15 days in glass jars, each of 10 l capacity. The remaining three groups of the fish were used as controls and each of them was kept in a pesticide-free medium. Equal concentration of acetone was maintained in the control as carbaryl added to the experimental aquaria was dissolved in acetone. Acetone was used as a solvent for carbaryl since it is known to be non-toxic up to relatively high concentration (Sharma and Gopal, 1995). The fish were fed with boiled egg white and small pieces of goat liver in adequate amount. No mortality of the fish occurred during the experimental period. The aquaria were aerated daily for 6 hr with compressed air using stone diffusers and the test medium of each experimental group was renewed once every 24 hr. Other conditions were the same as mentioned elsewhere (Sharma *et al.*, 1993b).

At the end of the experimental period, the fishes were sacrificed and dissected. The liver was excised and collected from controls as well as the experimental fish. The tissue was thoroughly washed in normal saline and stored at 4°C to be used within 2 hr. The blood samples (about 1 ml) collected by fish caudal vein puncture from each group were kept at 10°C for 15 min, centrifuged at $800 \times g$ for 10 min in a refrigerated centrifuge, and the serum collected was used for estimation of the activities of certain key enzymes and the levels of some biomolecules.

The homogenate (10%, w/v) of liver (1 g) was prepared in cold sucrose solution (0.25 M) using Potter-Elvehjem homogenizer, the homogenate was centrifuged at $10,000 \times g$ for 15 min in a refrigerated centrifuge, and the supernatant was collected for assay of the activities of certain enzymes. Protein in the serum as well as in the tissue extracts was determined according to Lowry *et al.* (1951). The estimations of inorganic phosphate (Oser, 1979), glucose (Park and Johnson, 1963), cholesterol (Zlatkis *et al.*, 1953) and lactic acid (Barker and Summerson, 1941) were done in serum using standard procedures. The activities of lactate dehydrogenase (EC 1.1.1.28, LDH) (Kaushal and Sharma, 1985), acid phosphatase (EC 3.1.3.2) (Plummer, 1971), alkaline phosphatase (EC 3.1.3.1) (Plummer, 1971), glutamate oxaloacetate transaminase

(EC 2.6.1.1, GOT) (Bergemeyer, 1965) and glutamate pyruvate transaminase (EC 2.6.1.2, GPT) (Bergemeyer, 1965) were determined in the serum and liver extract. The activity of succinate dehydrogenase (EC 1.3.99.1, SDH) was assayed in the liver extract (Srikantan and Krishnamurti, 1955).

Statistical analysis

All quantitative data were expressed as mean $\pm$ SD, and evaluated statistically. The differences between chemical-treated and control groups were analysed using Student's *t*-test (Fisher, 1950). The significant level was set at $p < 0.05$.

RESULTS

The carbaryl-treated fish exhibited apparent changes in body color (from pinkish gray to dark gray), opercular movement, surfacing and swimming activities when compared to that of controls. Carbaryl caused significant alterations in the levels of some biochemical indices (total protein, inorganic phosphate, glucose, cholesterol and lactic acid) as well as in the activities of some key enzymes (LDH, acid and alkaline phosphatases, GOT and GPT) in the serum of *C. batrachus* exposed to three sublethal concentrations of carbaryl (1, 2 and 4 mg/l) for two different periods i. e. 96 hr and 15 days.

The average concentrations of total protein, inorganic phosphate, glucose, cholesterol and lactic acid in

the serum of the control fish were found to be 3870 ± 180 , 45.75 ± 4.47 , 65.31 ± 7.31 , 427.51 ± 29.81 and 432 ± 31.07 mg/100 ml respectively (Table 1).

The levels of total protein and glucose decreased in the blood of *C. batrachus* treated with subacute concentrations of carbaryl for two different exposure periods (Tables 1 and 2). The decrease in the levels of these biochemical constituents was more prominent (about 30 and 24% respectively) when the fish were exposed to a higher concentration (4 mg/l) of the pesticide for a prolonged period of exposure (15 days). The levels of inorganic phosphate, cholesterol and lactic acid registered an increase in serum of the fish exposed to varying subacute concentrations of the pesticide at both exposure periods. The alteration in the level of lactic acid in the fish serum was more marked than that of other parameters (Tables 1 and 2) after both treatment durations (96 hr and 15 days), the values being higher at 96 hr compared to that of 15 days. The pesticide at 1 mg/l concentration was less effective than at its higher concentrations (2 and 4 mg/l). The level of serum lactic acid concentration, however, did not increase significantly after 2 mg/l for 96 hr (from 40% to 42%) or 15 days (from 35% to 36%) (Tables 1 and 2). The elevation in blood lactic acid level may be attributed to the damage of fish organs due to pesticide toxicity. However, very little change (up to 5%) was recorded in the level of cholesterol in the serum of carbaryl-treated *C. batrachus* over controls.

The average values of the activities of some key

Table 1. Effect of carbaryl on the levels of certain biomolecules in the blood serum of *C. batrachus* exposed for 96 hr.

Parameters	Control	Carbaryl (mg/l)		
		1	2	4
Total protein (g/100 ml)	3.87 ± 0.18	3.72 ± 0.16 (-3.87)	3.41 ± 0.18 (-11.89)	3.00 ± 0.17 (-22.48)
Inorganic-Phosphate (mg/100 ml)	45.75 ± 0.47	46.23 ± 0.48 (+1.05)	48.32 ± 0.51 (+5.62)	53.11 ± 0.12 (+16.01)
Glucose (mg/100 ml)	65.31 ± 3.01	63.53 ± 3.02 (-2.73)	60.37 ± 3.04 (-7.73)	58.13 ± 3.02 (-10.99)
Cholesterol (g/100 ml)	0.42 ± 0.02	0.43 ± 0.03 (+2.38)	0.44 ± 0.03 (+4.76)	0.44 ± 0.02 (+4.76)
Lactic acid (g/100 ml)	0.43 ± 0.31	0.48 ± 0.28 (+11.63)	0.60 ± 0.31 (+39.53)	0.61 ± 0.33 (+41.86)

Each value represents the mean $\pm$ S.E.M. of five different observations. Values in parentheses are percent change over control.

Sample size (n) = 15

enzymes such as LDH, acid phosphatase, alkaline phosphatase, GOT and GPT in the serum of the control fish were recorded to be 1.13 ± 0.11 , 1.51 ± 0.31 , 0.32 ± 0.03 , 0.28 ± 0.01 and 0.03 ± 0.001 IU/mg protein, respectively (Table 3). The exposure of *C. batrachus* to carbaryl resulted in drastic alterations in the activities of these enzymes in the fish serum. The results presented in Tables 3 and 4 demonstrate that carbaryl at sublethal concentrations evoked a significant increase in the levels of the enzymes in fish serum at both treatment durations. The increase in the activities of these enzymes was more pronounced when the fish was exposed to carbaryl at all subacute concentrations (1, 2 and 4 mg/l) for a longer period of exposure (15 days) than that for a shorter treatment duration (96 hr). However, the increase in the activities of transaminases (GOT and GPT) was higher than that of phosphatases (acid and alkaline) and LDH in the serum of pesticide-treated fish (Tables 3 and 4).

When the activities of these enzymes were assayed in the extract of the liver of the fish exposed to subacute concentrations of the pesticide for 15 days, it was found that carbaryl induced perturbations in the activities of LDH, acid phosphatase and GOT, whereas small but significant changes were recorded in the activities of alkaline phosphatase and GPT (Table 5). The activities of LDH, SDH and phosphatases (both acid and alkaline) were found to be decreased by 35, 24, 19 and 7%, respectively, with a concomitant increase in the activ-

ities of GPT (7%) and GOT (122%) when the fish was exposed to carbaryl (4 mg/l) for 15 days. The increase in the activity of GOT in fish liver was, however, much higher than that of GPT due to carbaryl intoxication. The results suggested that the fish liver functions were severely affected by the pesticide.

DISCUSSION

Pesticides at subacute concentrations have been shown to affect energy metabolism (Sastry and Siddiqui, 1982; Sharma and Gopal, 1995; Singh and Sharma, 1998), neurotransmission (Sharma *et al.*, 1993a, 1993b), synthesis of lipids and proteins (Saxena *et al.*, 1988), immune systems (Gopal *et al.*, 1992) and the activities of certain key enzymes of some fresh-water fishes (Sastry and Siddiqui, 1982; Sharma *et al.*, 1993a; Sharma and Gopal, 1995). The results of the present study demonstrated the increased levels of inorganic phosphate, cholesterol and lactic acid and decreased levels of total proteins and glucose in the serum of *C. batrachus* exposed to carbaryl at three sublethal concentrations (1, 2 and 4 mg/l) for two incubation periods (96 hr and 15 days); indicating thereby the toxic effects of the pesticide on the fish. Similar results have been reported in *Channa punctatus* exposed to sublethal concentrations of quinolphos (Sastry and Siddiqui, 1984) and monocrotophos (Samuel and Sastry, 1989) as well as in *C. batrachus* exposed to organophosphorus insecticides.

Table 2. Effect of carbaryl on the levels of certain biomolecules in the blood serum of *C. batrachus* exposed for 15 days.

Parameters	Control	Carbaryl (mg/l)		
		1	2	4
Total protein (g/100 ml)	3.87 ± 0.18	3.59 ± 0.20 (-7.25)	3.18 ± 0.25 (-17.83)	2.70 ± 0.33 (-30.23)
Inorganic-Phosphate (mg/100 ml)	45.75 ± 2.70	47.25 ± 2.31 (+3.28)	50.32 ± 2.53 (+9.98)	56.84 ± 2.68 (+24.24)
Glucose (mg/100 ml)	65.30 ± 3.30	61.43 ± 3.45 (-5.93)	57.89 ± 3.31 (-11.35)	50.01 ± 3.02 (-23.41)
Cholesterol (g/100 ml)	0.43 ± 0.09	0.44 ± 0.06 (+2.33)	0.45 ± 0.08 (+4.65)	0.46 ± 0.06 (+6.98)
Lactic Acid (g/100 ml)	0.45 ± 0.09	0.54 ± 0.06 (+18.32)	0.61 ± 0.06 (+35.56)	0.61 ± 0.04 (+35.56)

Each value represents the mean $\pm$ S.E.M. of five different observations. The values in parentheses denote percent change over control.

Sample size (n) = 15

Carbaryl induced biochemical changes in *Clarias batrachus*.**Table 3.** Effect of carbaryl on the activities of some enzymes from serum of *C. batrachus* exposed to the pesticide for 96 hr.

Enzymes	Control	Carbaryl (mg/l)		
		1	2	4
LDH ^a	1.13 ± 0.11	1.18 ± 0.11 (+4.42)	1.24 ± 0.13 (+9.73)	1.13 ± 0.12 (+22.12)
AcP ^b	1.51 ± 0.31	1.61 ± 0.32 (+6.62)	1.79 ± 0.29 (+18.54)	2.06 ± 0.34 (+36.42)
AlP ^b	0.32 ± 0.03	0.35 ± 0.01 (+9.34)	0.37 ± 0.03 (+15.63)	0.40 ± 0.04 (+25.0)
GOT ^c	0.28 ± 0.01	0.32 ± 0.04 (+14.29)	0.39 ± 0.03 (+39.29)	0.52 ± 0.02 (+85.71)
GPT ^c	0.03 ± 0.001	0.04 ± 0.001 (+33.33)	0.05 ± 0.001 (+66.66)	0.06 ± 0.001 (+100)

a μ moles of NADH oxidized to NAD⁺/hr/mg protein.b μ moles of p-nitrophenol released/hr/mg protein.c μ moles of pyruvate released/hr/mg protein.Each value represents the mean $\pm$ S.E.M. of five different observations. The values in parentheses denote percent change over control.

Sample size (n)=15

Abbreviations: LDH, lactate dehydrogenase; AcP, acid phosphatase; AlP, alkaline phosphatase; GOT, glutamate oxaloacetate transaminase; GPT, glutamate pyruvate transaminase.

Table 4. Effect of carbaryl on the activities of some enzymes from the serum of *C. batrachus* exposed to the pesticide for 15 days.

Enzymes	Control	Carbaryl (mg/l)		
		1	2	4
LDH ^a	1.13 ± 0.12	1.29 ± 0.13 (+14.16)	1.48 ± 0.12 (+30.97)	1.68 ± 0.11 (+48.67)
AcP ^b	1.51 ± 0.31	1.72 ± 0.31 (+13.91)	1.98 ± 0.31 (+31.13)	2.24 ± 0.32 (+48.34)
AlP ^b	0.32 ± 0.03	0.38 ± 0.03 (+18.75)	0.42 ± 0.03 (+31.25)	0.50 ± 0.04 (+56.25)
GOT ^c	0.28 ± 0.11	0.35 ± 0.10 (+25.00)	0.48 ± 0.11 (+71.43)	0.58 ± 0.12 (+107.43)
GPT ^c	0.03 ± 0.004	0.04 ± 0.006 (+33.33)	0.05 ± 0.007 (+66.67)	0.07 ± 0.008 (+133.33)

a μ moles of NADH oxidized to NAD⁺/hr/mg protein.b μ moles of p-nitrophenyl released/hr/mg protein.c μ moles of pyruvate released/hr/mg protein.Each value represents the mean $\pm$ S.E.M. of five different observations. The values in parentheses denote percent change over control.

Sample size (n)=15

Abbreviations: LDH, lactate dehydrogenase; AcP, acid phosphatase; AlP, alkaline phosphatase; GOT, glutamate oxaloacetate transaminase; GPT, glutamate pyruvate transaminase.

ticides (Pant *et al.*, 1987) and carbofuran (Mukhopadhyay *et al.*, 1982). However, in *C. punctatus* the level of lactic acid was shown to decrease when the fish was exposed to quinolphos and monochrotophos (Samuel and Sastry, 1989) for a longer period of time (60 days). The accumulation of lactic acid (the end product of glycolysis) in serum and the decrease in the activity of succinate dehydrogenase in the liver is an indication of the inhibition of Kreb's cycle and/or a favor of anaerobic metabolism over aerobic metabolism due to intoxication by carbaryl (Sharma and Gopal, 1995). It also indicates the continuous operation of the glycolysis in fish tissues to meet the immediate energy demand and a portion of lactate being channelled into the blood (Sharma and Gopal, 1995). Further, the increased level of LDH activity in serum (Tables 3 and 4) indicates that the pesticide causes damage to fish tissues. The increased level of lactic acid has also been reported by Sastry and Siddiqui (1982) in *C. punctatus* exposed to sevin (1.05 mg/l) up to 60 days. The blood glucose level decreased in the pesticide-treated fish as compared to that of control, indicating thereby a hypoglycemic response. It has been shown that intestinal uptake of

glucose is reduced in *C. batrachus* exposed to quinolphos (Sastry and Siddiqui, 1984). The low rate of absorption of glucose by the brush border in the intestine of the fish may be another possible reason for the hypoglycemic condition observed in the present study (Samuel and Sastry, 1989). The observed hypoglycemia could also be due to the increased rate of conversion of glucose into lactate under anaerobiosis to meet the energy demand by the organism for its survival (Sharma and Gopal, 1995; Singh and Sharma, 1998). The decrease in blood glucose level in *C. punctatus* exposed to endosulfan (0.2 mg/l) for 60 days has also been reported by Sastry and Siddiqui (1983).

The results of the present investigation suggested little influence of the carbaryl intoxication on the fish blood lipid profile (Tables 1 and 2). However, in another fresh-water fish, *Barbus conchoni*, exposed to aldicarb for 15 days, a marked increase in the level of cholesterol has been reported (Pant *et al.*, 1987). Alkaline phosphatase is a brush border enzyme involved in the transphosphorylation reaction. In serum of carbaryl-treated *C. batrachus*, the rise in the activities of alkaline phosphatase reflects alterations in the protein syn-

Table 5. Effect of carbaryl on the activities of certain key enzymes in the liver of *C. batrachus* exposed for 15 days.

Enzymes	Control	Carbaryl (mg/l)		
		1	2	4
LDH ^a	1.09 ± 0.01	1.00 ± 0.09 (-8.26)	0.94 ± 0.05 (-13.76)	0.70 ± 0.05 (-35.78)
SDH ^b	27.35 ± 0.81	25.18 ± 0.83 (-7.93)	22.8 ± 0.71 (-16.64)	20.81 ± 0.67 (-23.91)
AcP ^c	2.86 ± 0.12	2.60 ± 0.11 (-9.09)	2.53 ± 0.12 (-11.54)	2.31 ± 0.11 (-19.23)
AIP ^c	0.97 ± 0.02	0.95 ± 0.02 (-2.06)	0.93 ± 0.02 (-4.12)	0.90 ± 0.01 (-7.22)
GOT ^d	0.37 ± 0.03	0.41 ± 0.03 (+11.92)	0.59 ± 0.03 (+59.08)	0.82 ± 0.03 (+123.30)
GPT ^d	0.50 ± 0.012	0.511 ± 0.011 (+2.0)	0.513 ± 0.014 (+4.39)	0.534 ± 0.010 (+6.59)

a μ moles of NADH oxidized to NAD⁺/hr/mg protein.

b μ moles of formazan formed/hr/mg protein.

c μ moles of p-nitrophenol released/hr/mg protein.

d μ moles of pyruvate released/hr/mg protein.

Each value represents the mean $\pm$ S.E.M. of five different observations. The values in parentheses denote percent change over control.

Sample size (n) = 15

Abbreviations: LDH, lactate dehydrogenase; SDH, succinate dehydrogenase; AcP, acid phosphatase; AIP, alkaline phosphatase; GOT, glutamate oxaloacetate transaminase; GPT, glutamate pyruvate transaminase.

thesis and uncoupling of oxidative phosphorylation. Acid phosphatase is a lysosomal enzyme which aids the autolysis of the cell after its death. The increase in the level of this enzyme in serum of *C. batrachus* may be due to structural damage in the liver and hence the leakage of the enzyme into extracellular compartments caused by carbaryl toxicity (Mahajan and Sharma, 1984; Shobharani *et al.*, 1989; Gill *et al.*, 1990).

The increase in the activities of GOT and GPT in the blood of *C. batrachus* exposed to carbaryl for 96 hr and 15 days suggested that there was increase in the transamination processes and also that protein was increasingly metabolized. This notion is further supported by the decrease in the level of protein under pesticide stress (Tables 1 and 2). The cellular damage during pesticide stress may also cause mitochondrial enzyme to seep into the cytoplasm, thus enhancing the enzyme activities. Similar findings are reported in *C. batrachus* exposed to sublethal concentrations of carbofuran (0.1 to 0.5 mg/l) (Mukhopadhyay *et al.*, 1982; Kumari *et al.*, 1997; Yadav *et al.*, 1998) and in *C. punctatus* exposed to subacute concentrations of aldicarb for 30 days (Pant *et al.*, 1987). GOT and GPT are often used to assess the impact of sublethal toxicity of environmental pollutants in fish (Loroux and Perry, 1972). The present results showing an increase in the activities of GOT and GPT in liver (Table 5) and the serum (Tables 3 and 4) suggest probable alterations in the pathophysiological status of the liver as well as an increased turnover of protein in *C. batrachus* due to pesticide toxicity.

In conclusion, carbaryl at sublethal concentrations exerted its toxic manifestations in *C. batrachus* leading to the onset of an energy crisis. The decrease in the activity of carbaryl-treated SDH in the liver and increase in lactic acid content in blood of *C. batrachus* suggest an impairment of aerobic processes in favor of anaerobic processes, possibly to meet the energy requirement due to pesticide intoxication. The observed alterations in energy metabolism may also be a reflection of toxic effects such as inhibition of acetylcholinesterase (AChE) activity by carbaryl in *C. batrachus* (Sharma *et al.*, 1993a), which leads to increased motor activity and thus creates higher energy demands. This is supported by the increase in the activities of transaminases which may be helpful in energy supplementation through gluconeogenesis. Thus, it appears that the pesticide has induced an energy crisis and altered the protein metabolism, forcing the fish to adapt an alternative energy-producing mechanism to survive. Further studies are in progress to understand the exact mechanism(s)

involved in the biochemical changes following carbaryl treatment.

ACKNOWLEDGMENTS

The financial support from the All India Council for Technical Education-New Delhi is acknowledged.

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