

## Effects of taurine on cadmium exposure in muscle, gill, and bone tissues of *Carassius auratus*

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### Abstract

This study was performed in order to investigate the effects of taurine on cadmium poisoning in muscle, gill, and bone tissues of wild goldfish. For this experiment, 80 wild goldfish were divided into four experimental groups: 0.3 mg/L of cadmium and 0 mg/L of taurine (Group I), 0.3 mg/L of cadmium and 20 mg/kg of taurine (Group II), 0.3 mg/L of cadmium and 40 mg/L of taurine (Group III), and 0.3 mg/L of cadmium and 80 mg/L of taurine (Group IV). The results were as follows: The cadmium concentration in muscle tissue of wild goldfish was 0.65-3.21 mg/kg wet wt in Group I, whereas it decreased in Group IV. Levels of cadmium in gill tissue of wild goldfish were 16.57-42.39 mg/kg wet wt in Group I, 15.23-43.01 mg/kg wet wt in Group II, 15.11-39.56 mg/kg wet wt in Group III, and 13.15-38.55 mg/kg wet wt in Group IV ( $P < 0.05$ ), suggesting that the cadmium concentration decreased in the experimental groups compared to control. The cadmium concentration in bone tissue of wild goldfish after 28 days was 0.52-9.75 mg/kg in Group II, whereas it increased in Group III ( $P < 0.05$ ). In conclusion, taurine may have a preventive effect against cadmium accumulation in biological tissues.

**Key Words:** Cadmium, wild goldfish, muscle, gill, bone

### Introduction

Cadmium is a metal widely used in electric plating, plastic stabilizers, batteries, etc. However, widespread application of cadmium has resulted in pollution of water, air, and soil, along with increased accumulation in livestock, fish, and shellfish. Cadmium accumulated in drinking water and air eventually accumulates in the body, causing a number of diseases such as hypertension, osteomalacia, gastric dysfunction, CNS dysfunction, and endocrine disorders [1-6].

Taurine is a  $\beta$ -amino acid in which the carboxyl group on the  $\alpha$ -carbon is substituted for sulfonic acid, and it exists as a free amino acid in animal tissues and biological fluids. Biosynthesis of taurine is achieved by the process in which cysteine is converted into cysteine sulfinate by cysteine deoxygenase, followed by hypotaurine and cysteric acid formation by decarboxylase and oxidase. In a previous experiment, the concentrations of GABA (gamma-aminobutyric acid) and taurine were measured in the hypothalamus, median eminence, striatum, and prefrontal cortex of mice following cadmium exposure. The authors observed decreased GABA levels in every area of the brain except the striatum, and similar levels of taurine were measured in all areas except the mediobasal hypothalamus and striatum [7].

Taurine is a sulfur-containing amino acid that combines with

bile acid in the liver. It has been reported to have a chemical structure similar to that of acetylcysteine with heavy-metal detoxifying effects. In a study on the effects of ascorbic acid, garlic extract, and taurine on cadmium chelation in catfish, the cadmium concentration significantly decreased [8,9].

Therefore, in this study, we investigated the effects of taurine on cadmium accumulation in muscle, gill, and bone tissues of exposed wild goldfish.

### Materials and Methods

#### Experimental design

*Carassius auratus*, or wild goldfish, was captured in Kyungchun reservoir located in Wanju-gun, Jeollabuk-do. After 15 days in the laboratory, healthy-looking fish with a size of 51-62 mm and weight of 4.2-9.2 g were selected. Cadmium chloride ( $\text{CaCl}_2 \cdot \text{H}_2\text{C}$ ), ammonium citrate, nitric acid, ammonium sulfate, hydrochloric acid, ammonium hydroxide sodium dimethyl dithiocarbamate, and methyl isobutyl ketone were of analytical grade (Sigma Co, USA). Taurine was obtained from DongA Pharmaceutical Co.

This paper was supported by the Sahmyook University Research Fund in 2010.

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Received: March 14, 2012, Revised: December 27, 2012, Accepted: December 29, 2012

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### Feeding conditions and analysis

The size of the water reservoir was 60 × 30 × 30 cm, and pH, dissolved oxygen (DO), and water temperature levels were maintained at 7.0 ± 0.3, 7.3 ± 1.5 mg/L, and 17-21 °C, respectively. Fish were maintained at room temperature. Cadmium chloride (CaCl<sub>2</sub>·H<sub>2</sub>C) was added to the water reservoir at a concentration of 0.3 mg/kg, whereas taurine (Donga Pharm.) was added at concentrations of 0 mg/kg, 20 mg/kg, 40 mg/kg, and 80 mg/kg for groups I-IV, respectively. During the experiment, test groups were fed tetra bits (Tetra Germany) twice a day at the same amount. Glass plasticware that were used in storage of samples and analysis for Cd were cleansed in 3.2 N nitric acid (for 24 h) and rinsed at least five times with distilled deionized water. For analyses of diets and tissues, samples were placed in Erlenmeyer flasks and 2-4 ml of 12 N nitric acid was added. Samples were digested (100 °C) and then evaporated and diluted with distilled deionized water to appropriate volumes. Cd was determined by from atomic absorption spectrophotometry (Varian spectro AA-30, at wave length 228.8 nm).

### Statistical analysis

Statistical analyses were performed using SPSS (Ver. 18.0), and Duncan's multiple-range tests were used to examine differences among each experimental group ( $P < 0.05$ ).

## Results

### Cadmium contents in muscle, gill, and bone without taurine

In our study, cadmium levels in wild goldfish were 0.02 ± 0.02 mg/kg in muscle, 0.15 ± 0.05 mg/kg in gill, and 0.05 ± 0.02 mg/kg in bone tissues (Table 1). In group I, the cadmium concentrations in muscle were 0.65 ± 0.11 mg/kg in the 7-day treatment group and 3.21 ± 0.27 mg/kg in the 28-day treatment group. In gill, cadmium concentrations were 16.57 ± 2.72 mg/kg in the 7-day treatment group and 27.15 ± 3.11 mg/kg in the 28-day treatment group. In bone, cadmium concentrations were 1.97 ± 0.16 mg/kg in the 14-day treatment group and 9.86 ± 2.16 mg/kg in the 28-day treatment group. These results show increased cadmium accumulation in tissues in proportion to the period of cadmium exposure ( $P < 0.05$ ).

**Table 1.** Contents of cadmium of wild goldfish muscle, gill and bone exposed cadmium, 0.3 mg/L and treated without taurine (unit : mg/kg)

	Muscle	Gill	Bone
0 day	0.02 ± 0.02	0.15 ± 0.05	0.05 ± 0.02
7 day	0.65 ± 0.11	16.57 ± 2.72*	0.51 ± 0.05
14 day	0.67 ± 0.09	27.15 ± 3.11*	1.97 ± 0.16
21 day	2.09 ± 0.41	33.85 ± 1.98*	7.92 ± 1.75
28 day	3.21 ± 0.27	42.39 ± 4.15*	9.86 ± 2.16

Values are the mean ± SD.  
\*  $P < 0.05$

### Cadmium contents in muscle, gill, and bone fed 20 mg/L taurine

In group II, the cadmium concentration in muscle was 0.51 ± 0.05 mg/kg in the 7-day treatment group, which is a decrease compared to that of group I over the same treatment period. However, in the 21-day treatment group, no significant difference in cadmium concentration was observed between the taurine and non-treated groups (2.09 ± 0.41 mg/kg in taurine group and 2.08 ± 0.26 mg/kg in non-treated group) (Table 2). In gill, cadmium concentrations were 24.69 ± 6.15 mg/kg in the 14-day treatment group and 43.01 ± 3.16 mg/kg in the 28-day treatment group, which were particularly remarkable compared to other organs. The cadmium concentration in bone was not significant until after week 1, whereas a rapid increase was observed from 3 weeks ( $P < 0.05$ ).

### Cadmium contents in muscle, gill, and bone fed 40 mg/L taurine

In group III, the cadmium concentration in muscle was 0.49 ± 0.12 mg/kg in the 7-day treatment group, which was slightly lower than that of group II. On the other hand, the cadmium level in muscle was 2.11 ± 0.35 mg/kg in the 21-day treatment group, which was slightly higher than that of group II ( $P < 0.05$ ) (Table 3). In gill, cadmium concentrations were 15.11 ± 1.97 mg/kg and 39.56 ± 5.37 mg/kg in the 7- and 28-day treatment groups, respectively ( $P < 0.05$ ). This result demonstrates increased cadmium levels in gill tissue in proportion to exposure time.

**Table 2.** Contents of cadmium of wild goldfish muscle, gill and bone exposed cadmium, 0.3 mg/L and treated with 20 mg/L taurine (unit : mg/kg)

	Muscle	Gill	Bone
7 day	0.51 ± 0.05	15.23 ± 3.51*	0.52 ± 0.07
14 day	0.68 ± 0.12	24.69 ± 6.15*	1.87 ± 0.31
21 day	2.08 ± 0.26	31.91 ± 4.25*	8.12 ± 0.96
28 day	3.11 ± 0.35	43.01 ± 3.16*	9.75 ± 3.11

Values are the mean ± SD.  
\*  $P < 0.05$

**Table 3.** Contents of cadmium of wild goldfish muscle, gill and bone exposed cadmium, 0.3 mg/L and treated with 40 mg/L taurine (unit : mg/kg)

	Muscle	Gill	Bone
7 day	0.49 ± 0.12	15.11 ± 1.97*	0.51 ± 0.05
14 day	0.58 ± 0.09	25.35 ± 3.26*	1.91 ± 0.23
21 day	2.11 ± 0.35	31.85 ± 7.53*	7.78 ± 0.96
28 day	2.96 ± 0.27	39.56 ± 5.37*	9.89 ± 1.51

Values are the mean ± SD.  
\*  $P < 0.05$

**Table 4.** Contents of cadmium of wild goldfish muscle, gill and bone exposed cadmium, 0.3 mg/L and treated with 80 mg/L taurine (unit : mg/kg)

	Muscle	Gill	Bone
7 day	0.51 ± 0.11	13.15 ± 2.09*	0.50 ± 0.06
14 day	0.55 ± 0.17	24.77 ± 6.21*	1.95 ± 0.36
21 day	1.85 ± 0.21	31.01 ± 10.16*	7.95 ± 1.27
28 day	2.89 ± 0.33	38.55 ± 6.93*	9.11 ± 0.99

Values are the mean ± SD.  
\*  $P < 0.05$

### Cadmium contents in muscle, gill, and bone fed 80 mg/L taurine

In group IV, cadmium levels in muscle were  $0.51 \pm 0.11$  mg/kg,  $0.55 \pm 0.17$  mg/kg,  $1.85 \pm 0.21$  mg/kg, and  $2.89 \pm 0.33$  mg/kg in the 7-, 14-, 21-, and 28-day treatment groups, respectively (Table 4). The cadmium concentration in gill was  $16.57 \pm 2.72$  mg/kg in the non-treated group, whereas it slightly decreased to  $15.23 \pm 3.51$  mg/kg,  $15.11 \pm 1.97$  mg/kg, and  $13.15 \pm 2.09$  mg/kg in groups II-IV, respectively, with increasing taurine concentration. However, there was no statistically significant difference between the groups ( $P < 0.05$ ).

### Discussion

In recent times, there has been an increase in pollutants in river and coastal waters with the development of industry. Emission of heavy metals contaminates water and plankton populations, which are the main feed for fish. As a result, heavy metals in fish and shells progress through the food chain, accumulating in the human body and causing various diseases. Cadmium is absorbed mainly through the respiratory and digestive systems, and target organs have been reported to be the lung and kidney. Further, it has been reported that cadmium may cause lung cancer and kidney dysfunction [10,11]. In particular, fish may partially absorb heavy metals through the skin, but most heavy metals are absorbed through the gills, resulting in respiratory organ damage. It was reported that absorbed heavy metals interact with the base and phosphate groups of nucleic acids, resulting in nuclear dysfunction and cancer [12]. Moreover, it has been reported that taurine alters the phospholipid and fatty acid contents of the liver, thereby affecting lipid metabolism and reducing the level of cholesterol in the blood. It has also been shown that taurine alters the lipid content of the liver as well as inhibits changes in fatty acid composition induced by ingestion of cholesterol [13]. Taurine is known to impact the development of tissues and organs in animal cells, and it was shown that taurine deficiency increases the probability of stillborn or aborted fetuses. Especially, taurine is closely related to brain function as it is present in the central nervous system [14]. Taurine is a sulfur-containing amino acid abundant in animal tissues. It is known that taurine is synthesized from cysteine intermediates in the liver [15]. It has been shown that protein excretion is higher with an abundance of cysteine, as a higher amount of metallothionein-Cd in the renal tubules decreases adsorption of metallothionein-Cd in the blood [10]. In addition, taurine is abundant in the skeletal muscle, pituitary gland, and retina, and mediates various physiological functions such as calcium metabolism, facilitation of glucose metabolism, and stabilization of cell membranes.

Taurine is a sulfur-containing  $\beta$ -amino acid synthesized in the liver from methionine and cysteine and has been reported to mediate neural regulation, cell membrane stabilization, and osmotic pressure control [16]. Cadmium exists in two forms *in*

*in vivo*, metallothionein-Cd and non-metallothionein-Cd, the former of which is minimally toxic due to the stability of cadmium, unless decomposed. On the other hand, non-metallothionein-Cd is reportedly very toxic [17]. Fish commonly used in experiments on heavy metal exposure or toxicity include minnow, crucian carp, carp, goldfish, and loach [18]. Taurine has further been reported to be an effective therapy for chronic dysfunction of cadmium-exposed mice. In other words, taurine affects a number of enzymes in tissues exposed to cadmium, including superoxide dismutase, catalase, glutathione-S-transferase, glutathione reductase, and glutathione superoxide [19]. Taurine is excreted via urine or bile contained in bile acid, and amount of injection affects biosynthesis of taurine *in vivo*, to increase the activity of cholesterol 7 $\alpha$ -hydroxylase and LDL receptor, facilitating cholesterol metabolism in the liver [20]. The interaction between taurine and metal is an electrical interaction between the sulfonate ion of taurine and metal cations. Further, the metal and chelation product is reported to be protective against metal-induced toxicity [21]. Especially, taurine plays an important role in estrogen deficiency, which inhibits reduction of bone mass after menopause [22]. A previous study examined the effects of ascorbic acid, garlic extract, and taurine on oxidative stress induced by cadmium by measuring cadmium levels in the kidney and liver of catfish. The results showed that cadmium levels in the liver and kidney of catfish significantly increased upon exposure to cadmium. However, the levels of cadmium in organs decreased upon treatment with ascorbic acid, garlic extract, and taurine [9]. In a report that examined the effect of taurine treatment on oxidative stress induced by cadmium in the liver, rats were exposed to cadmium chloride and their organ weights measured. The results showed that cadmium levels rapidly increased in the liver, whereas liver organ weights decreased. However, it was found that ingestion of taurine reversed the liver damage in rats induced by cadmium [23]. Thus, taurine is effective for the detoxification of cadmium. In this study, carp were treated with different concentrations of taurine (0 mg/kg, 20 mg/kg, 40 mg/kg, and 80 mg/kg) after exposure to cadmium, followed by measurement of cadmium levels in various tissues. According to our results, as the concentration of taurine increased, cadmium levels decreased in muscle, gill, and bone tissues of carp.

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