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The Protective Effect of Aluminosilicates in Laying Hens Chronically Intoxicated with Thallium

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Abstract

The purpose of this investigation was to study the effects of aluminosilicates (vermiculite and bentonite), added to feed on thallium bioaccumulation in laying hens. The experiment was conducted on 48 layers kept in cages under vivarium conditions. The hens were divided into 4 groups: Group 1- control, Group 2 – thallium-intoxicated, Group 3 – thallium-intoxicated fed on feed containing vermiculite and Group 4 – thallium-intoxicated fed on feed containing bentonite. Thallium was added in the form of sulphate (Tl_2SO_4) at a daily dose of 0.74 mg/kg body weight. Thallium content was determined in blood and eggs on days 1, 14, 28, 42, 56 of the experiment and also in thigh and breast muscles, kidney, liver and thigh bone after the experiment was accomplished. Thallium content of the tissues and organs was determined using plasma spectrometry ICP-MS. The highest thallium concentration was found in bones 8.849 mg/kg, next in kidneys 7.596 mg/kg. Lower thallium content was found in muscles, liver and blood. The addition of bentonite reduce thallium accumulation most effective in muscles by 34.75-36.94% and blood 39.07%. The addition of vermiculite to the feed had reducing impact on thallium accumulation in the all tested tissues and organs of birds chronically intoxicated with this element (by 18.2% in kidneys – 55.71% in breast muscles).

Keywords: thallium, laying hens, vermiculite, bentonite

Introduction

Thallium is a metal belonging to Group III A (boron family), which occurs in trace amounts in the natural environment. The environment can be contaminated with thallium in the regions of coal mines, cement plants and nonferrous metal industry, especially copper and zinc [13, 14]. Thallium is a major component of industrial dusts and can be transported over long distances, and with precipitation it can fall to waters, soil and other links of the trophic chain, causing danger to human health [2, 7, 10].

Chronic intoxication with thallium in humans and animals causes dysfunction of the nervous, cardiac, vascular, and reproduction systems as well as skin (alopecia) [5]. Dmowski et al. [4] claim that there is a real danger of thallium contamination of the environment, which may result in accumulation of this element in animals. Thallium contamination in farm animals may cause the hazard of animal origin food safety. The purpose of the present study was to examine the distribution and accumulation of thallium in hens chronically intoxicated with feed containing this element and the reducing effects of aluminosilicates (vermiculite and bentonite) on bioaccumulation of thallium in laying hens.

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Experimental Procedures

The experiment was conducted on 48 ISA Brown laying hens, aged 56 weeks. The hens were kept in cages (2

hens per cage) under vivarium conditions. The experiment was carried out for 8 weeks, preceded by a two-week adaptive period. The hens were divided into 4 Groups, each containing 12 birds:

- Group 1 – control fed standard feed mixture DJ.
- Group 2 – fed standard feed mixture DJ + 16 mg Tl/kg of feed.
- Group 3 – fed standard feed mixture DJ +16 mg Tl/kg of feed + 3% of vermiculite.
- Group 4 – fed standard feed mixture DJ +16 mg Tl/kg of feed + 3% of bentonite.

Thallium was added to the feed in the form of sulphate (Tl_2SO_4). Eggs and blood samples were collected for the measurements of thallium concentration on days 1, 14, 28 and 56 during the experimental period. The experiment was accomplished on day 56, on which the hens were euthanized. The following tissues and organs were then collected for the measurements of thallium content: breast m., thigh m., liver, kidney, and thigh bone. Mineralization of samples for thallium measurements was performed in a high-pressure rotation microwave oven CEM (USA) with spectrally pure nitric acid. Thallium content was determined using plasma spectrometry ICP-MS (Varian Ultramas 700) [8]. All data were analyzed using Statgraphics 5.0 software [16] by analyses of variance (ANOVA) to test for the effects of treatments. When a significant treatment effect was observed, a Duncan's multiple range test was used to compare means. Treatment effects were considered with the significant level at $p \leq 0.05$ and $p \leq 0.01$.

Results

Table 1 shows the mean values of thallium concentration in blood throughout the experimental period. The highest level was found in Group 2 for the entire period of study. The mean thallium content during intoxication period was 214.96 µg/l and it was 358-fold higher than in the control group. Thallium concentration in blood in Group 3 (fed bentonite) averaged 128.22 µg/l and it was 40.4% lower ($p \leq 0.01$) than that in Group 2. Thallium content of blood in Group 4 (fed vermiculite) averaged 135.53 µg/l and it was 37% lower ($p \leq 0.01$) than that in Group 2.

Thallium content of blood in Groups 3 and 4 remained at a significantly higher level ($p \leq 0.01$) than the control group.

Table 2 shows mean levels of thallium in tissues under investigation. When thallium was added to the feed, a significant increase in thallium content of the tissues was observed in all experimental Groups (2, 3 and 4). The highest Tl accumulation was found in thigh bones and kidneys. The highest Tl accumulation (8.849 mg/kg of fresh matter) in thigh bone was found in Group 2 and it was 227 times as high as in the control group. Also in Group 2 the highest mean concentration (7.596 mg/kg of fresh matter) of thallium was in kidneys and it was 227 times as high as that in the control group. The organ that accumulated the lowest Tl quantity was liver. In Group 2, the mean Tl concentration in hen's liver was 1.439 mg/kg of fresh matter, which was 50 times as high as that of the control group (Group 1).

The addition of bentonite to the feed (Group 3) did not significantly decrease Tl concentration in kidney, thigh bone or liver, as compared to Group 2. In contrast, vermiculite addition to the feed reduced Tl concentration in kidney, thigh bone and liver of hens. These values were lower than those noted in Group 2 by 17.6%, 21.8% and 33.5%, respectively. However, despite the reducing effect of vermiculite, the concentration of Tl remained higher than that in the control group. Tl concentration in breast muscles in the control group (Group 1) averaged 0.014 mg/kg of fresh matter and was 0.001 mg/kg of fresh matter. higher than that in thigh muscles. The highest mean levels of Tl in muscles were found in Group 2 – 2.648 mg/kg of fresh matter (breast muscle) and 2.818 mg/kg of fresh matter (thigh muscle). The addition of bentonite to the feed (Group 3) reduced Tl concentration in breast muscle by 38.1% and 34.8% in thigh muscle as compared to Group 2. In Group 4, fed feed containing vermiculite, these values were lower by 56.5% (breast m.) and 47.5% (thigh

Table 1. Thallium concentration in hens' blood [µ/l].

Day of experiment	Group 1		Group 2		Group 3		Group 4	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	$\bar{X}$
1	0.53	0.08	0.55	0.06	0.51	0.15	0.54	0.04
14	0.76^{ABC}	0.44	173.23^{ADa}	1.79	112.17^{BD}	9.75	129.01^{Ca}	30.73
28	0.51^{ABC}	0.07	226.48^{ADE}	5.07	113.80^{BD}	16.13	129.12^{CE}	22.14
42	0.57^{ABC}	0.23	225.06^{ADE}	30.99	119.61^{BDF}	3.38	139.82^{CEF}	9.65
56	0.57^{ABC}	0.08	235.09^{ADE}	17.03	167.29^{BD}	37.96	144.19^{CE}	7.72
$\bar{X}$ Days 14-56	0.60^{ABC}	0.11	214.96^{ADE}	28.17	128.22^{BD}	26.24	135.53^{CE}	7.68

AA, BB, CC, DD, EE, FF – significant differences between groups ($p \leq 0.01$), aa – significant differences between groups ($p \leq 0.05$)

m.). Although Tl accumulation in Groups 3 and 4 was significantly reduced, its concentration still remained at a high level as compared to the control group.

The highest concentrations of Tl in whole eggs were found in Group 2 ($p \leq 0.01$) and averaged 3.812 mg/kg of fresh matter, which was 228-fold higher than in the control group.

The addition of bentonite to the feed (Group 3) significantly reduced Tl concentration in whole eggs (by 14.3% on average) as compared to Group 2 ($p \leq 0.01$). Also vermiculite (Group 4) decreased Tl concentration in whole eggs (by 19.8% on average) as compared to Group 2 ($p \leq 0.01$). Tl concentration in whole eggs in the vermiculite Group was lower than that found in the bentonite Group, but a significant difference between the two Groups occurred on day 56 of the experiment. Despite a significant reducing effect of aluminosilicates on Tl concentration in whole eggs, the level of Tl remained 192 times as high in Group 3 and 179 times as high in Group 4 as compared to the control.

Discussion

In our own studies Tl concentration in blood depended on the time of exposure and was markedly lower as compared to other tissues. Distribution of thallium from blood to other tissues is very fast. The biological half-life of Tl in blood of rats is below 5 minutes [18, 19]. The results obtained in our studies on the distribution of thallium in hen tissues show that the highest concentration of this element occurs in bones, and next in kidney, muscles and liver. Ueberschär et al. [19] studied Tl accumulation in tissues of hens intoxicated with thallium (at doses 2 to 40 mg Tl/kg of feed) and found the highest Tl concentrations in kidneys, next in bones, muscles and liver. The highest concentration of Tl in kidneys is due to kidney filtration and intracellular accumulation of thallium [3]. The results of our studies show that chronic Tl intoxication results in high Tl accumulation in whole eggs. The data in literature show that Tl accumulation in birds' eggs has not been studied extensively. Kemper and Bertram [9] are the only authors who reports that in the region close to a cement plant in Lengerich (Germany), Tl concentration in whole eggs was 1.26 mg/kg fresh matter, 0.394 mg/kg of fresh matter in egg white and yolk and 4.94 mg/kg of fresh matter in eggshells.

Vermiculite and bentonite (aluminosilicates) are compounds of mineral origin, with complex-forming, sorption and ion-exchange properties. There are many reports in literature showing that aluminosilicates are used for decontamination of organisms after radioactive exposure

Table 2. Thallium concentration in hens' tissues [mg/kg of fresh matter].

Tissues	Group 1		Group 2		Group 3		Group 4	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Breast m.	0.014^{ABC}	0.004	2.649^{ADE}	0.228	1.639^{BDF}	0.150	1.151^{CEF}	0.039
Thigh m.	0.013^{ABC}	0.004	2.818^{ADE}	0.010	1.838^{BDF}	0.011	1.474^{CEF}	0.094
Liver	0.029^{ABC}	0.002	1.439^{AD}	0.341	1.370^{BE}	0.271	0.957^{CDE}	0.025
Kidneys	0.042^{ABC}	0.009	7.596^{AD}	0.405	7.378^{BE}	0.469	6.259^{CDE}	0.683
Bones	0.039^{ABC}	0.013	8.849^{AD}	0.775	8.267^{BE}	0.282	6.921^{CDE}	0.660

AA, BB, CC, DD, EE, FF – significant differences between groups ($p \leq 0.01$).

Table 3. Thallium concentration in eggs [mg/kg of fresh matter].

Day of experiment	Group 1		Group 2		Group 3		Group 4	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
1	0.020	0.003	0.018	0.003	0.018	0.002	0.017	0.001
14	0.016^{ABC}	0.003	3.509^{ADa}	0.413	3.018^{Ba}	0.273	2.880^{CD}	0.102
28	0.011^{ABC}	0.003	3.759^{ADE}	0.069	3.171^{BE}	0.153	2.981^{CD}	0.332
42	0.021^{ABC}	0.005	3.830^{ADE}	0.235	3.270^{BE}	0.310	3.157^{CD}	0.233
56	0.019^{ABC}	0.001	4.151^{ADE}	0.162	3.609^{BEF}	0.087	3.216^{CDF}	0.319
$\bar{X}$ Days14-56	0.017^{ABC}	0.003	3.812^{AD}	0.264	3.267^{BE}	0.251	3.058^{CDE}	0.115

AA, BB, CC, DD, EE, FF – significant differences between groups ($p \leq 0.01$), aa – significant differences between groups ($p \leq 0.05$).

and detoxication after poisoning with mycotoxins. However, there are very few publications on the use of these compounds for reducing the accumulative effects of heavy metals, inclusive of thallium, in animals. Kuzniecow and Muchina [11] observed lower concentrations of copper, lead, cadmium, chromium, and nickel in meat of broilers fed on feed containing vermiculite. The efficiency of aluminosilicates in reducing cadmium accumulation has been reported by Pond and Yen [15], Anke et al. [1] and Kramer et al. [12]. Feldhofer [6] found that bentonite reduced the accumulation of cadmium, chromium and lead in calves, broilers and fattening pigs. The results of the studies show that aluminosilicates, especially vermiculite, added to the feed of hens chronically intoxicated with thallium, are able to reduce accumulation of this element in tissues and organs.

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