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THE EFFECT OF DIETARY CADMIUM AND ZINC ON LIPIDS, PROTEINS AND CARBOHYDRATES IN RATS

S. V. Rana, V. P. Agrawal and N. G. Bhardway

School of Environmental Contamination and Toxicology, Department of Zoology, D. A. V. (P. G.) College, Muzaffarnagar-251001, India

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The effects of dietary cadmium and zinc on the protein, lipid and carbohydrate content of the rat's liver and kidneys were determined. For both zinc and cadmium fed rats data indicate a loss of total proteins and lipids from the liver and kidneys respectively, and a carbohydrate increase in both organs. Comparable results were obtained for rats subject to the combined treatment. Physiological antagonism, adaptive behaviour of these tissues, formation of free fatty acids, aldolase, glucose-6-phosphatase and other metabolic requirements are also discussed.

While the essentiality of zinc in animal and human nutrition has long been recognized (1, 2) cadmium is known to be virtually toxic to every system of the animal body (3, 4). As in both cases rapid accumulation and turnover occur in the liver and kidneys (5, 6) the hepatotoxic and nephrotoxic behaviour of the two metals has been studied in detail (7, 8). However, the diversity of their function in protein, lipid and carbohydrate metabolism is not well understood. Protein-bound cadmium has been associated with emphysema, and other pulmonary diseases in patients (9). On the other hand, zinc deficiency is known to impair the utilization of amino acids in the protein synthesis (10). Since these elements elicit specific responses, protein induction processes, reactions with lipids and modifications in carbohydrates were thought to be useful parameters in explaining the mechanism of zinc and cadmium induced toxicity. In this paper, total proteins, carbohydrates and lipids were determined in the liver and kidneys of rats fed cadmium and zinc. Since cadmium and zinc are known as antagonists, the effects of their com-

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bined treatment on these parameters were also estimated. Great concern about zinc and cadmium poisoning due to industrial exposure and environmental contamination makes these data important to industrial toxicology and environmental hygiene.

MATERIAL AND METHODS

Forty male albino rats of the Charless Foster strain, 90 days old, weighing 100 ± 10 g were selected from the laboratory stock. They were divided at random in four groups of ten rats each. Rats were housed in appropriate separate cages and fed a standard laboratory diet (free from cadmium) obtained from Hindustan Lever Ltd, Bombay. They received tap water ad libitum. The rats in Group I received cadmium sulphate by gavage in a dose of 0.50 g/kg body weight daily for thirty days. Rats in Group II were given a dose of 5 g zinc acetate per kg body weight, and those in Group III were fed a mixture of both elements in a ratio of 1:1, a total dose of 0.50 g/kg body weight of each element for thirty days. These doses were selected to get a response in a shorter time. Group IV, which received laboratory diet alone and tap water ad libitum, served as control. The diet was kept constant throughout the experiment. After thirty days, all the rats were starved for 24 hours and killed by decapitation. The liver and kidneys were quickly removed and the wet weight was recorded. Total proteins were estimated by means of bovine serum albumin (BSA) as standard (11). Total lipids were extracted from the dried samples by a Soxhlet extractor using chloroform and ether as solvents (12). Carbohydrates were determined with orcinol reagent (13). Statistical significance was determined by Student's »t« test (14).

RESULTS AND DISCUSSION

No effect of zinc and cadmium was observed on the moisture content of the liver (Table 1). However, in the kidneys an increase in moisture was recorded after zinc treatment. Cadmium caused a mild fall in the moisture content of the kidney (Table 2). These general effects can be correlated with the greater accumulation of these ions in the kidneys than in the liver. Data on total proteins indicate their loss from the kidneys in cadmium and zinc fed rats. The combined treatment also caused protein depletion from the kidneys. Available examples of metal protein interactions (15, 16, 17) suggest that specific responses are elicited by these elements. Present observations stand in agreement with other reports (18, 19), indicating that proteins undergo a regulation in response to changes in the microenvironment. Since impairment in the synthesis of proteins is an expression of abnormality in the synthesis or degradation of RNA or both (20), the results reported earlier (21) further

Table 1.

Moisture, total proteins, lipids and carbohydrates in the liver of rats fed Cd, Zn or both Zn and Cd (Mean ± SEM in 5 rats)

Content (%)	Control	Treatment		
		Cadmium	Zinc	Cd + Zn
Moisture	70.49±2.05	70.42±0.04	70.49±0.20	69.19±0.570
Total proteins	8.50±0.92	8.00±0.57	7.60±0.37	8.42±0.005
Total lipids	13.18±1.06	6.08±0.37**	6.56±0.115**	16.05±0.004*
Total carbohydrates	7.83±1.18	11.50±1.27	12.05±0.588*	4.34±1.200

*P < 0.05; **P < 0.001 (Fisher's »t« test)

Table 2.

Moisture, total proteints, lipids and carbohydrates in the kidneys of rats fed Cd, Zn or both Zn and Cd (Mean ± SEM in 5 rats)

Content (%)	Control	Treatment		
		Cadmium	Zinc	Cd + Zn
Moisture	74.43±1.16	72.38±0.910	76.31±1.150	76.19±0.590
Total proteins	12.50±1.05	7.14±0.155**	5.77±0.115***	7.36±0.023**
Total lipids	8.09±0.92	6.40±0.155	5.37±0.002*	5.00±1.004
Total carbohydrates	4.98±1.24	11.08±1.160***	9.54±0.590*	8.45±1.73

*P < 0.05; **P < 0.01; ***P < 0.001 (Fisher's »t« test)

confirm the above hypothesis for zinc. However, a decrease in DNA dependent RNA polymerase activity as suggested by *Terhune* and *Sandstead* (22) also seems to be a probable reason. It is known that the cadmium binding proteins in the liver and kidneys of adult rats increase in proportion to the cadmium dose (23). It was confirmed that these binding proteins are not normal constituents of these tissues, but are synthesized in response to the uptake of cation (8). Nevertheless, a gradual loss of proteins from these organs shows an adaptive behaviour of their parenchyma to exceeding limits of cadmium and zinc ions in their fluids.

Present observations on total lipids show their depletion by cadmium and zinc in the liver. Though similar statistics is not available, both cations might have decreased the input of free fatty acids (FFA) averting the formation of FFA. Stimulation of aldolase (24) and pre-existing enzyme(s) resulting in a decreased capacity of the liver microsomes as described earlier (25) seems to be a suitable explanation. Elevated lipid values recorded after the combined treatment could be explained by a reverse hypothesis.

Data thus obtained on carbohydrates were different than for lipids and proteins. Both elements stimulated carbohydrates in the liver and kidneys. The combined treatment exerted a favourable effect in the kidneys only. Changes in carbohydrate metabolism are known to occur in zinc-deficient rats (26), but the effects of a continued ingestion are not known. Though the exact mechanism still remains far from being elucidated, the problem appears to be associated with the membranous glucose-6-phosphatase and microsomes.

It is concluded that cadmium and zinc exert specific effects on moisture, total proteins, total lipids and total carbohydrates due to: 1. varying rates of accumulation, 2. removal of the component by interactions between metals and enzymes, 3. varying rates of excretion, 4. different binding sites and 5. depletion of metals from tissues. Furthermore, hepato-renal handling of these metals depends on metabolic requirements, homeostatic control and physiological adaptations.

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Sažetak

UČINAK KADMIJA I CINKA U HRANI NA KOLIČINU LIPIDA, BJELANČEVINA I UGLJIKOHIDRATA U ŠTAKORA

Autori su istraživali učinak kadmija i cinka dodavanih hrani pojedinačno i u kombinaciji na razinu lipida, bjelančevina i ugljikohidrata u jetri i bubrezima štakora. I cink i kadmij izazvali su smanjenje količine lipida i bjelančevina u bubrezima dok su oba metala izazvala povećanje koncentracije ugljikohidrata i u jetri i u bubrezima. Različitost učinaka na istraživanim organima autori pripisuju razlikama u kumuliranju cinka i kadmija u dva organa.

Škola za onečišćenje okoliša i toksikologiju,
Odjel za zoologiju,
Muzaffarnagar, Indija

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