Maternal Dietary Zinc, and Development and Zinc, Iron, and Copper Content of the Rat Fetus [1,2,3]

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ABSTRACT High levels (0.2 and 0.4%) of zinc were fed to adult female rats beginning at either 0-day age of the fetus or 21 days before breeding to study the development and iron, copper, and zinc status of the 15- to 20-day-old fetus. Growth reduction in terms of dry matter or variable degrees of death and resorption occurred in fetuses from mothers fed 0.4% zinc; 100% resorption occurred in the 15- and 16-day-old fetus of mothers fed 0.4% zinc beginning at 21 days before breeding. Fetal development was normal in the fetus of mothers fed 0.2% zinc beginning at 21 days before breeding. No external anatomical malformations were observed in the fetus from zinc-fed mothers. Total zinc and concentration of zinc were significantly higher in the 15- to 20-day-old fetus of mothers fed 0.4% zinc. No significant elevation of zinc occurred in the fetus from mothers fed 0.2% zinc. Reduced total iron and concentration of iron was the trend found in the fetus from mothers fed excess zinc; the reduction was significant only in the 16- and 18-day-old fetus from mothers fed 0.4% zinc beginning at 0-day age of the fetus. Liver iron was not reduced in the 18-day-old fetus; the decrease in the fetus, therefore, was a reflection of the significant reduction of body iron. Copper was significantly reduced in the fetus from zinc-fed mothers except the 15- and 16-day-old fetus from mothers fed 0.4% zinc beginning at 0-day age of the fetus. No significant change was found in maternal liver, but trends showed liver iron to be increased in mothers fed 0.4% zinc for 15 and 16 days and decreased with the other zinc regimens. With the exception of mothers fed 0.4% zinc for 15 days of fetal age, copper content in the liver was significantly reduced by all zinc regimens.

Excess dietary zinc has been shown to cause a reduction in liver iron and copper in the rat (1–4) and liver iron in the pig (5). Although the mechanism of the zinc antagonism to iron and copper is obscure, available data suggest a decreased ability of ferritin and hemosiderin to store iron (6), a shortened life span of erythrocytes resulting in a faster turnover of iron (7), and an impairment of copper absorption as mediated primarily via the direct effects of zinc either in or on the intestine (8). The above studies were conducted with either weanling or adult rats. No data are available on the effect of excess zinc in the diet of the maternal animal on fetal zinc, iron, and copper, and scant information was found on the development of the fetus. Sutton and Nelson (9) noted stillbirths and reduced numbers of newborn from rats fed a diet containing 0.5% zinc for 14 to 17 weeks before and during gestation. Kinnamon (10) reported no resorption and no difference in the number per litter and average wet weight of rat fetuses from mothers fed a diet containing 0.5% zinc for 53 days before and during gestation. Although zinc accumulated in the liver of the fetal lamb, no adverse effect on development occurred in the fetuses of yearling ewes given a daily dosage of 5 mg zinc sulfate/kg body weight during the gestation period (11). The present investigation was designed to determine the effect of a high level of zinc in the diet of the female rat on fetal development; the iron, copper, and zinc relation in fetal tissue; and the iron, copper, and zinc relation in the maternal animal.

EXPERIMENTAL PROCEDURE

General. Nulliparous female rats,[4] ranging in weight from 160 to 190 g, were

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[3] Presented in part before the 51st Annual Meeting of the Federation of American Societies for Experimental Biology, Chicago, 1967. A portion of this paper was taken from a thesis submitted by the senior author to the Graduate School, Pennsylvania State University, in partial fulfillment of the requirements for the degree of Master of Science.

[4] CFE strain of Sprague-Dawley rats obtained from Carworth, New City, New York.

individually housed in wire cages and received feed and distilled water ad libitum. The composition of the basal diet was as follows: (in %) casein, 20; sucrose, 63; cellulose,[5] 2; corn oil, 10; salt mixture,[6] 4; and vitamin mixture,[7] 1. Excess zinc diets were made by the incorporation of either 0.2 or 0.4% zinc as zinc oxide into the basal diet. The diets contained 7.5 ppm of copper and 230 ppm of iron.

Mating was performed as previously described (12), and the day sperm was found in the vaginal smear was designated as 0-day age of the fetus. At the appropriate age of the fetuses, the mothers were stunned by a blow on the head, decapitated, exsanguinated, and maternal liver and fetuses removed via abdominal incision. Because of fetal size, the 15- and 16-day-old fetuses from individual mothers were pooled. For the 18- and 20-day-old fetuses, the liver was removed from each fetus and the livers and the bodies [8] of the fetuses from each mother were pooled separately. Therefore, the value for the older fetus is the mathematical sum of the determined values for liver and body.

All specimens were dried to a constant weight at 100°. The dried samples were wet-digested with nitric and sulfuric acid, and analyzed for zinc (13), copper (14), and iron (15).

Experiment 1. Ten female rats were fed the 0.4% zinc diet and ten were fed the basal diet beginning at 0-day age of the fetus. At each fetal age of 15 and 16 days, 5 experimental and 5 basal rats were killed.

Experiment 2. Twenty female rats were treated according to the same regimen as described in experiment 1 with the exception that the animals were killed at fetal ages of 18 and 20 days.

Experiment 3. Twenty female rats were subjected to the same regimen as stated in experiment 1 with the exception that the rats were fed the diets for 21 days before mating and continued to be fed the diets during the development of the fetus.

Experiment 4. Ten female rats were subjected to the same regimen as given in experiment 3 with the exceptions that the experimental diet contained 0.2% zinc, and the rats were killed only at a fetal age of 15 days.

RESULTS

Excess zinc (0.4%) in the diet of the maternal rat beginning at 0-day age of the fetus caused a significant reduction in growth (in terms of dry matter) of the 15- to 20-day-old fetus (table 1). Growth reduction was also reflected by a significantly smaller liver size of the 18- and 20-day-old fetus. Although variable degrees (4–29%) of fetal resorption occurred with this regimen, no external anatomical malformations were observed. Extension of the feeding of 0.4% zinc to 21 days before mating caused 100% resorption of the 15- and 16-day-old fetuses. In trials to determine at what fetal age resorption was initiated on the regimen of 0.4% zinc beginning at 21 days before mating, 36 and 40% resorption was found for the 12- and 14-day-old fetus, respectively. Feeding a 0.2% zinc diet beginning at 21 days before mating did not affect fetal growth in terms of dry matter, cause any significant degree of resorption, nor cause any anatomical malformations in 15-day-old fetuses.

Data illustrating the amount of zinc, iron, and copper expressed as total (μg) and concentration (ppm) of the individual fetus, liver, and body on a dry weight basis are given in tables 2, 3, and 4, respectively.

Total zinc and the concentration of zinc were significantly higher in the 15- to 20-day-old fetus of maternal rats fed the 0.4% zinc diet during pregnancy. The body of the 18- and 20-day-old fetus and the liver of the 20-day-old fetus from mothers fed zinc contained significantly higher total zinc and concentration of zinc. The liver of the 18-day-old fetus, however, did not contain a significantly increased total or concentration of zinc. Fetus from the maternal rat fed 0.2% zinc beginning at 21 days before mating contained about the

[5] Alphacel, Nutritional Biochemicals Corporation, Cleveland.

[6] Jones, J. H., and C. Foster, J. Nutr., 24: 245, 1942 (obtained from Nutritional Biochemicals Corporation).

[7] Vitamins in cornstarch, amount/kg of diet: vitamin A, 20,000 IU; vitamin D, 2,200; (in milligrams) ascorbic acid, 1017; vitamin E as α-tocopheryl acetate, 485; inositol, 110; choline dihydrogen citrate, 3715; menadione, 49.6; *p*-aminobenzoic acid, 110; niacin, 99.2; riboflavin, 22; pyridoxine·HCl, 22; thiamine·HCl, 22; Ca pantothenate, 66; biotin, 0.44; folic acid, 1.98; and vitamin B_{12}, 29.7 μg (obtained from General Biochemicals, Inc., Chagrin Falls, Ohio).

[8] In this report, the term body, such as body iron, is used to mean the fetus minus the liver.

TABLE 1

Effect of excess dietary zinc for the maternal rat on growth and viability of fetus

Diet	Fetal age [1]	Dry weight			Resorption [2]
		Fetus	Liver	Body	
	days	*mg*	*mg*	*mg*	*%*
		Experiment 1			
Basal	15	21.2± 0.7 [3]			0(12)
0.4% Zn	15	16.2± 1.1 **			29(9)
Basal	16	40.2± 1.7			0(12)
0.4% Zn	16	31.5± 1.5 **			11(10)
		Experiment 2			
Basal	18	131.8± 3.5	18.3±0.5	113.5± 3.3	0(12)
0.4% Zn	18	98.7± 8.0 **	11.5±1.7 **	87.2± 6.6 **	19(11)
Basal	20	421.9±11.2	49.3±3.7	372.6±11.1	0(11)
0.4% Zn	20	317.0±24.5 **	31.3±4.6 **	286.7±20.2 *	4(10)
		Experiment 3			
Basal	15(36)	22.9± 3.2			0(13)
0.4% Zn	15(36)				100(0)
Basal	16(37)	37.9± 1.4			0(11)
0.4% Zn	16(37)				100(0)
		Experiment 4			
Basal	15(36)	20.9± 0.1			1(12)
0.2% Zn	15(36)	20.7± 0.1			1(10)

[1] Day sperm found in vaginal smear counted as 0-day age of fetus; days pregnant animals were fed diets. Numbers in parentheses are total number of days females were fed diets.
[2] Criteria for resorption were fetuses in all stages of resorption and total resorption with implantation site evidence of fertilization. Numbers in parentheses are average number of viable fetuses.
[3] Average value per fetus, liver, or body and SE of mean.
* Significantly different from basal value, $P < 0.05$.
** Significantly different from basal value, $P < 0.01$.

same total zinc and concentration of zinc as the fetus from mothers fed the basal diet.

Reduced total iron and concentration of iron was the general trend in the fetus from mothers fed excess zinc. However, the reduction was significant in only the 16- and 18-day-old fetus from mothers fed 0.4% zinc. In this respect, no significant difference was found in total iron and concentration of iron in the liver of the 18-day-old fetus from mothers fed excess zinc. The reduction of iron in the fetus, therefore, was a reflection of the change in body iron; both total iron and concentration of iron were significantly reduced in the body of the 18-day-old fetus.

No significant reduction in total copper or concentration of copper occurred in the 15- and 16-day-old fetus from mothers fed a diet containing 0.4% zinc beginning at 0-day age of the fetus. The 18- and 20-day-old fetus from mothers fed zinc beginning at 0-day of the fetus had significantly reduced total copper and concentration of copper. Total copper and concentration of copper in the liver of these fetuses were also significantly reduced. Total copper and concentration of copper in the body, however, were only significantly reduced in the 18-day-old fetus; no change was found in the body of the 20-day-old fetus. Feeding the maternal rat a diet of 0.2% zinc beginning at 21 days before mating caused a significant reduction in total copper and concentration of copper in the fetus.

Data showing the amount of zinc, iron, and copper expressed as total (µg) and concentration (ppm) of the maternal liver on a dry-weight basis are tabulated in table 5.

A significant increase was found in total zinc and concentration of zinc in the liver of mothers on all zinc regimens. Lower total zinc and concentration of zinc were noted in the liver of the mothers fed 0.2% zinc as compared with those fed 0.4% zinc. No significant changes were observed in maternal liver iron. However, the liver of mothers fed 0.4% zinc for 15 and 16 days of fetal age contained a higher total and concentration of iron, whereas the other regimens resulted in a lower total iron and concentration of iron. With the

TABLE 2
Effect of excess dietary zinc for the maternal rat on zinc content of the fetus

Diet	Fetal age [1]	Fetus [2]		Liver [2]		Body [2]	
		Total	Concentration	Total	Concentration	Total	Concentration
	days	*µg*	*ppm*	*µg*	*ppm*	*µg*	*ppm*
Experiment 1							
Basal	15	0.9±0.2	43.1±11.7				
0.4% Zn	15	1.7±0.2 *	104.8±15.3 *				
Basal	16	1.6±0.3	38.7± 6.5				
0.4% Zn	16	4.1±0.6 **	131.1±21.2 **				
Experiment 2							
Basal	18	4.4±0.8	33.3± 5.8	3.0±0.7	164.7± 38.4	1.4±0.3	12.4±3.1
0.4% Zn	18	6.6±0.4 **	66.5± 6.7 **	3.4±0.4	348.7±100.4	3.2±0.1 **	36.8±2.0 **
Basal	20	11.6±1.4	27.4± 3.3	5.5±1.3	109.5± 23.8	6.1±0.4	16.4±1.5
0.4% Zn	20	28.3±1.3 **	89.3± 7.4 **	7.7±1.2 **	257.4± 33.0 **	20.6±0.4 **	74.1±7.1 **
Experiment 4							
Basal	15(36)	1.1±0.2	51.7± 8.1				
0.2% Zn	15(36)	1.4±0.2	68.0±11.1				

[1] See footnote 1, table 1.
[2] Average value of total content and concentration in fetus, liver, or body on dry-weight basis and SE of mean.
* Significantly different from basal value, $P < 0.05$.
** Significantly different from basal value, $P < 0.01$.

TABLE 3
Effect of excess dietary zinc for the maternal rat on iron content of the fetus

Diet	Fetal age [1]	Fetus [2]		Liver [2]		Body [2]	
		Total	Concentration	Total	Concentration	Total	Concentration
	days	*µg*	*ppm*	*µg*	*ppm*	*µg*	*ppm*
Experiment 1							
Basal	15	3.6±0.3	168.7± 6.9				
0.4% Zn	15	2.5±0.5	155.0± 31.6				
Basal	16	7.6±0.5	188.5± 5.4				
0.4% Zn	16	4.3±0.4 **	138.6± 13.3 **				
Experiment 2							
Basal	18	14.3±2.2	108.5± 19.9	3.0±0.7	161.5±37.2	11.3±1.8	101.1±19.0
0.4% Zn	18	8.3±2.1 *	84.1± 11.7 *	3.5±1.1	316.5±84.0	4.8±0.4 **	54.5± 0.9 *
Basal	20	21.2±4.1	50.3± 8.9	5.9±0.9	118.8±12.5	15.3±3.3	40.9± 8.4
0.4% Zn	20	16.3±3.4	51.4± 9.0	5.1±1.4	168.2±33.3	11.2±2.2	39.5± 6.8
Experiment 4							
Basal	15(36)	6.0±2.4	284.4±116.2				
0.2% Zn	15(36)	4.4±1.1	208.4± 48.7				

[1] See footnote 1, table 1.
[2] See footnote 2, table 2.
* Significantly different from basal value, $P < 0.05$.
** Significantly different from basal value, $P < 0.01$.

TABLE 4
Effect of excess dietary zinc for the maternal rat on copper content of the fetus

0.2% Zn	15(36)	4.4 ± 1.1	208.4 ± 48.7

[1] See footnote 1, table 1.
[2] See footnote 2, table 2.
* Significantly different from basal value, $P < 0.05$.
** Significantly different from basal value, $P < 0.01$.

TABLE 4
Effect of excess dietary zinc for the maternal rat on copper content of the fetus

Diet	Fetal age [1]	Fetus [2]		Liver [2]		Body [2]	
		Total	Concentration	Total	Concentration	Total	Concentration
	days	*µg*	*ppm*	*µg*	*ppm*	*µg*	*ppm*
Experiment 1							
Basal	15	0.9 ± 0.2	43.5 ± 10.2				
0.4% Zn	15	0.7 ± 0.3	44.4 ± 21.9				
Basal	16	0.8 ± 0.2	18.9 ± 4.2				
0.4% Zn	16	0.6 ± 0.2	18.7 ± 7.7				
Experiment 2							
Basal	18	1.9 ± 0.1	14.0 ± 0.9	1.2 ± 0.1	61.7 ± 6.4	0.7 ± 0.1	6.5 ± 1.2
0.4% Zn	18	0.5 ± 0.1 **	5.3 ± 1.6 **	0.2 ± 0.1 **	23.3 ± 9.6 *	0.3 ± 0.1 **	3.7 ± 1.0 *
Basal	20	2.9 ± 0.4	6.9 ± 0.9	1.5 ± 0.4	31.3 ± 3.0	1.4 ± 0.3	3.8 ± 0.7
0.4% Zn	20	1.5 ± 0.3 *	5.0 ± 1.1 *	0.3 ± 0.1 **	10.2 ± 2.8 **	1.2 ± 0.3	4.5 ± 1.0
Experiment 4							
Basal	15(36)	0.4 ± 0.05	19.9 ± 2.6				
0.2% Zn	15(36)	0.2 ± 0.04 **	8.8 ± 1.8				

[1] See footnote 1, table 1.
[2] See footnote 2, table 2.
* Significantly different from basal value, $P < 0.05$.
** Significantly different from basal value, $P < 0.01$.

exception of the liver of mothers fed 0.4% zinc for 15 days of fetal age, total copper and concentration of copper were significantly reduced by all zinc regimens.

DISCUSSION

Since proper nutrition before and during pregnancy has such marked influences on physical and mental potential of the individual, increased research is being carried out in this area. Although much information has been obtained concerning the influence of the maternal diet in terms of an excess or a deficiency of a nutrient on such parameters as malformation, fetal resorption, and ultimate development of the individual, the basic metabolic lesions are poorly understood.

A normal estrous cycle and normal mating with fertilization and implantation were observed in female rats fed a diet containing either 0.2 or 0.4% zinc. During the development of the embryo or fetus from mothers fed 0.4% zinc, however, changes occurred in the amount of zinc, iron, and copper, and probably other metabolites, and death and resorption or reduced growth ensued.

Abnormal fetal development occurred coincident with the level of zinc in the maternal diet and the length of time the diet was fed. In addition to reduced growth, small percentages of fetal resorption at fetal age of 15 to 18 days were noted in rats fed 0.4% zinc beginning at 0-day age of the fetus. However, feeding 0.4% zinc to the female rat beginning at 21 days before breeding, resulted in 36, 40, and 100% resorption for 12-, 14-, and 15- and 16-day-old fetuses, respectively. Lowering the level of zinc in the diet to 0.2%, and feeding it beginning at 21 days before breeding, had no adverse effect on fetal development. Although the abnormal fetal development was similar to that reported by Sutton and Nelson (9), it is difficult to make direct comparisons since they fed a zinc diet to weanling rats instead of to the mature female. Why Kinnamon (10) found no adverse fetal development from mature females fed 0.5% zinc for 53 days cannot be explained.

Zinc was significantly elevated in the viable fetus of mothers fed 0.4% zinc.

Although the zinc content in the liver of the 18-day-old fetus from the mothers fed zinc was the same as in the liver of the fetus from mothers fed the basal diet, a significantly higher zinc content was present in the body. This variation in zinc uptake between liver and body, which was not observed in the 20-day-old fetus, suggests a difference in tissue uptake or retention of zinc. As a possible explanation, Kinnamon (10) reported a variation in the distribution of ^{65}Zn in 12- to 17-day-old fetuses. The highest activities, in order of decreasing ^{65}Zn concentration, were in calcifying bones; liver, spleen, and lumen of the large blood vessels; and in kidneys. The lack of an accumulation of zinc in the fetus of mothers fed 0.2% zinc suggests a placental barrier to the transfer of abnormal amounts of zinc to the fetus, which becomes ineffective at higher concentrations of zinc.

Changes observed for the iron and copper content of the fetus from mothers fed excess zinc resembled the reduction previously reported (1–4) for the weanling and adult rat fed excess zinc. Although the general trend was reduced fetal iron with all zinc regimens, the only significant reduction was in the 16- and 18-day-old fetus from mothers fed 0.4% zinc beginning at 0-day age of the fetus. In contrast, a significant reduction occurred in the copper content of the 18- and 20-day-old fetus, but not in the 15- and 16-day-old fetus. Copper was also significantly reduced in the fetus of mothers fed 0.2% zinc; however, the zinc content in the fetus was not elevated. These findings suggest that the antagonism of zinc with copper is mediated in the mother or the placenta rather than in the fetus. An iron reduction in the body, but not in the liver of the 18-day-old fetus, indicates that whereas iron in the liver of the weanling rat was lowered in 3 to 5 days after initiating the feeding of zinc (1), fetal liver was relatively stable to the antagonism of zinc. However, liver copper was reduced to a greater degree than body copper in the 18-day-old fetus.

The reduction in content of iron and copper suggests an altered synthesis of important iron and copper metabolites in the fetus, which may have precipitated the abnormal fetal development. Reduced activity of liver cytochrome oxidase and catalase (17), heart cytochrome oxidase (3), and liver xanthine oxidase (6) have been noted in rats fed excess dietary zinc. Since the activity of fetal liver and heart cytochrome oxidase does not peak until days 18 and 19 of fetal age, respectively (18), and since hepatic xanthine oxidase activity is absent in the fetus (16), ascribing fetal death and resorption to possible changes in these enzymes is tenuous. Changes in the activity of the enzymes may, however, play a role in the reduced growth of the fetus from mothers fed zinc. These aspects of the problem are being investigated in this laboratory.

The increase in the amount of zinc in the fetus suggests the possibility of abnormal fetal development, particularly death and resorption, as the result of a toxic condition due to zinc per se. Rather than a zinc toxicity, the elevation of zinc may cause abnormal metabolism by adversely affecting tissue or organ systems. An increased osmotic fragility observed (19) for erythrocytes incubated in vitro with solutions containing zinc has been reported (7) to occur in rats fed excess zinc.

With the exception of the liver of mothers fed 0.4% zinc beginning at 0-day age and extending to day 15 of fetal age, the copper content was significantly reduced in the liver of mothers on all zinc regimens as similarily reported (1–4) for the nonpregnant animal. In contrast with this earlier work, and, although statistically insignificant, the values for liver iron indicate that trends of either an increase occurred when 0.4% zinc was fed for the short period of 15 to 16 days or a decrease occurred when 0.2 or 0.4% zinc was fed for longer periods of time. The lack of more positive agreement with the earlier work may be explained by the difference in animal age, as the adult rat was used in the present study rather than the weanling animal and consequently the diet was fed for a shorter period of time.

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TABLE 5

Effect of excess dietary zinc on total and concentration of zinc, iron, and copper in maternal liver

Diet	Fetal age [1]	Total [2]			Concentration [2]		
		Zinc	Iron	Copper	Zinc	Iron	Copper
	days	*µg*	*µg*	*µg*	*ppm*	*ppm*	*ppm*
				Experiment 1			
Basal	15	125.5 ± 20.9	419.0 ± 155.6	42.9 ± 5.6	36.2 ± 5.3	119.2 ± 40.3	12.4 ± 1.3
0.4% Zn	15	495.0 ± 87.6 **	543.6 ± 145.1	26.5 ± 4.9	144.4 ± 24.5 **	157.6 ± 36.3	7.9 ± 1.6
Basal	16	112.7 ± 15.1	302.0 ± 65.4	56.0 ± 6.7	33.3 ± 5.6	84.4 ± 14.0	16.1 ± 1.4
0.4% Zn	16	521.2 ± 25.6 **	479.0 ± 80.1	27.5 ± 3.4 **	162.4 ± 8.9 **	149.3 ± 24.7	8.5 ± 1.0 **
				Experiment 2			
Basal	18	163.0 ± 6.6	464.3 ± 53.4	68.9 ± 4.2	40.1 ± 2.3	113.0 ± 12.2	16.8 ± 0.5
0.4% Zn	18	724.4 ± 38.7 **	384.6 ± 27.6	36.2 ± 4.9 **	187.1 ± 8.6 **	99.9 ± 8.5	9.4 ± 1.3 **
Basal	20	179.9 ± 14.4	410.0 ± 37.3	64.8 ± 4.9	47.4 ± 3.2	107.0 ± 6.1	16.9 ± 0.7
0.4% Zn	20	766.0 ± 67.1 **	334.0 ± 28.8	39.5 ± 4.3 *	211.8 ± 20.5 **	92.4 ± 8.6	11.0 ± 1.4 *
				Experiment 3			
Basal	15(36)	125.8 ± 13.3	294.0 ± 44.8	45.8 ± 4.5	40.3 ± 4.7	93.6 ± 14.7	14.5 ± 1.3
0.4% Zn	15(36)	456.8 ± 79.8 **	237.6 ± 18.8	16.3 ± 4.8 **	165.8 ± 35.8 **	84.7 ± 11.6	5.4 ± 1.5
Basal	16(37)	101.2 ± 6.1	409.8 ± 146.5	44.6 ± 2.6	31.4 ± 2.8	124.1 ± 42.8	13.7 ± 0.8
0.4% Zn	16(37)	691.4 ± 97.2 **	380.6 ± 95.0	21.1 ± 1.5 **	212.0 ± 38.1 **	112.5 ± 25.5	6.4 ± 0.5 **
				Experiment 4			
Basal	15(36)	123.0 ± 15.5	507.0 ± 113.9	68.8 ± 3.0	37.8 ± 4.0	154.0 ± 32.5	21.2 ± 0.7
0.2% Zn	15(36)	268.0 ± 11.6 **	274.4 ± 18.4	55.6 ± 4.6 *	85.8 ± 4.2 **	87.8 ± 6.1	17.7 ± 1.2 *

[1] See footnote 1, table 1.
[2] Average value of livers from 5 maternal rats; values for total content and concentration on dry-weight basis and include SE of mean.
* Significantly different from basal value, $P < 0.05$.
** Significantly different from basal value, $P < 0.01$.

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