Zinc Deficiency in Guinea Pigs (36642)

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(Introduced by E. G. McDaniel)
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Zinc has been shown to be an essential nutrient for plants, many animals, and man (1). A recent U.S. National Academy of Sciences publication (2) suggested that zinc may be required for the guinea pig. However, we have found no published reports of zinc deficiency in this animal. Therefore this study was designed to determine if guinea pigs require zinc for normal growth and development.

Materials and Methods. Twenty-three male, 4 day old guinea pigs of the Hartley strain weighing 91–135 g were allotted by weight to one of two experimental regimes. Seventeen animals were fed a semipurified zinc-deficient diet (Table I) containing 1.2 ppm zinc as analyzed by atomic absorption spectrophotometry (3). Six animals (controls) were fed the identical diet supplemented with 100 ppm zinc. The guinea pigs were housed individually in suspended stainless steel cages and given deionized water *ad libitum*. The experimental conditions were controlled to prevent the animals from obtaining zinc from their environment. Daily food intake and weight gain were recorded for each guinea pig. On Day 20 of this experiment the guinea pigs were sacrificed by exsanguination under ether anesthesia. The following tissues were removed and analyzed for zinc concentration by atomic absorption spectrophotometry (3, 4): Liver, esophagus, kidneys, adrenals, pancreas, spleen, testes, femur, and plasma. Differences in means were tested for significance by Student's t test (5).

Results. The composition of the zinc-deficient diet is compared in Table I with the standard Reid and Briggs (6) guinea pig diet. Polyethylene powder[1] containing 0.04 ppm zinc was used as the bulking agent instead of cellulose[2] used in the Reid and Briggs guinea pig diet because cellulose contained nearly 20 times as much zinc (0.79 ppm).

Both groups of guinea pigs consumed identical quantities of diet (an average of 12 g of diet daily over the 20 day period although they were fed *ad libitum*). The average weight gain for the animals fed the zinc deficient and supplemented diets is shown in Table II. The net weight gain and average food intake is low because both groups of animals did not readily accept the semipurified regime when first offered the diet and the resulting loss in weight during the first few days of the experiment is included in the computation of the net weight gain. By Day 20 the animals fed the zinc supplemented diet gained 26 ± 12 g (mean ± SD) compared with 19 ± 11 g for the guinea pigs fed the zinc deficient diet. Although the difference is not significant a trend toward decreased weight gain for the animals fed the zinc deficient diet is evident. In a preliminary study it was observed that after Day 20 the animals fed a zinc-deficient diet displayed loss of appetite, diarrhea, and unsteady gait, and tremor, and later succumbed. Such symptoms were not evident in the zinc-supplemented control animals.

Before sacrifice the guinea pigs fed the zinc-deficient diet displayed rough coats and

[1] Microthene, U.S. Industrials Chemical Co., Division of National Distillers and Chemical Corporation, Baltimore, MD.

[2] Whatman fibrous cellulose powder CF-1. W & R. Balston, Ltd., England.

TABLE I. Comparison of the Zinc-Deficient and Reid and Briggs (4) Guinea Pig Diets.

Ingredient	Reid and Briggs (4) (per 100 g of diet)	Zinc-deficient[a] (per 100 g of diet)
Protein, g	30.0 (casein)	33.0[b,c]
Corn starch, g	20.0	—
Sucrose, g	10.3	41.0
Glucose, g	7.8	—
Bulking agent, mg	15.0	15.0[d]
Oil, g	7.3 (corn)	5.0[e]
Salts, g	6.0	5.0[f]
Choline, g	0.2	0.4[g]
Inositol, g	0.2	0.01
Thiamine hydrochloride, mg	1.6	2.2
Riboflavin, mg	1.6	2.2
Pyridoxine hydrochloride, mg	1.6	2.2
Calcium pantothenate, mg	4.0	6.6
Niacin, mg	20.0	9.9
p-Aminobenzoic acid, mg	—	11.0
Biotin, mg	0.06	0.04
Folic acid, mg	1.0	0.2
Vitamin B_{12}, mg	0.004	2.9
α-tocopherol acetate, mg	2.0	48.5
Menadione, mg	0.2	4.9
Ascorbic acid, mg	200	102
Vitamin A, mg	0.6	3.9

[a] 1.2 ± 0.4 ppm zinc (mean $\pm$ SD).

[b] 30% Dried egg white, obtained from General Biochemicals, Chagrin Falls, O.

[c] 3% Casein hydrolysate (acid, salt free), obtained from General Biochemicals.

[d] Microthene, polyethylene powder, U.S. Industrials Chemical Co., Division of National Distillers and Chemical Corp., Baltimore, Md.

[e] Coconut oil.

[f] Hubbel–Mendel–Wakeman, obtained from General Biochemicals. Hubbel *et al.*, J. Nutr. **14**, 273 (1937).

[g] Dihydrogen citrate.

scaly dermatitis about the feet and mouth. These symptoms were not evident in the animals fed the zinc-sufficient diet. Many of the symptoms exhibited in the guinea pigs fed the zinc-deficient diet both in this study and in a preliminary investigation are similar to those found in zinc deficiency in other animals (7). There was a highly significant decrease in the plasma and femur zinc concentration in the guinea pigs fed the zinc-deficient diet (Table III). There were no differences in zinc content in the other tissues studied.

Discussion. The quantitative requirement of zinc for the guinea pig has not been determined in this study. Aliquots of commercial guinea pig laboratory chow[3] known to support normal growth contained from 56.9 to 69.2 ppm zinc as analyzed by atomic absorption spectrophotometry.

The guinea pig has been utilized extensively in the study of scurvy due to its inability to synthesize ascorbic acid from glucose (8). Ascorbic acid, due to its reducing action, has been demonstrated to assist in the utilization of iron, a nutrient sharing many characteristics with zinc. Ascorbic acid has also been shown to protect the tapetum lucidum in the dog's eye from loss of color produced by the drug ethambutol (9). It is believed that ethambutol-induced tapetal color loss is related to *in vivo* zinc chelation (10). The mechanism by which ascorbic acid protects the tapetum lucidum is unknown. Now that it has been shown by this study that the guinea pig requires a dietary source of zinc it would be interesting to study the relationship between zinc and ascorbic acid.

Summary. This study has demonstrated that the guinea pig does require zinc. The animals fed a zinc deficient diet (1.2 ± 0.4 ppm) had a significant ($p < 0.001$) decrease in the plasma and femur zinc concentration compared with those guinea pigs fed a diet containing 104 ± 8.4 ppm zinc. The quantitative requirement of zinc for the guinea pig has not been determined in this study. A possible use of the guinea pig in a study to investigate the relationship between zinc and ascorbic acid is discussed.

[3] Wayne Guinea Pig Diet. Allied Mills, Inc., Chicago, Ill. 60606.

TABLE II. Comparison of Weight Gain for Guinea Pigs Fed a Zinc-Deficient and Zinc-Supplemented Diet.

Diet	Dietary zinc (ppm)	Av net wt gain (g)		
		Days on diet		
		12	18	20
Zinc-supplemented (6)[a]	104 ± 8.4[b]	11 ± 10[c]	21 ± 11	26 ± 12
Zinc-deficient (17)	1.2 ± 0.4	15 ± 10	20 ± 10	19 ± 11

[a] Number of animals in parentheses.
[b] Mean ± SD. Zinc analyses were performed on several aliquots of diet.
[c] Mean ± SD.

TABLE III. Comparison of Plasma and Femur Zinc Concentrations for Guinea Pigs Fed a Zinc-Deficient and Zinc-Supplemented Diet.

Diet	Dietary zinc (ppm)	Plasma zinc (μg/100 ml)	Femur zinc (μg/g fresh wt)
Zinc-deficient (17)	1.2 ± 0.4	136 ± 21.8	139 ± 12.5
Zinc-supplemented (6)[a]	104 ± 8.4[b]	41.8 ± 12.2	76.3 ± 9.9
Significance level		$p < 0.001$	$p < 0.001$

[a] Number of animals in parentheses.
[b] Mean ± SD.

1. Prasad, R., Fed. Proc. **26**, 181 (1967).
2. "Nutrient Requirements of Laboratory Animals." National Academy of Sciences, National Research Council, Washington, D.C. (1962).
3. Smith, J. C., and Halsted, J. A., J. Nutr. **100**, 973 (1970).
4. Hackley, B., Smith, J. C., and Halsted, J. A., Clin. Chem. **14**, 1 (1968).
5. Snedecor, G. W., "Statistical Methods." Iowa State University Press, Ames (1956).
6. Reid, M. E., and Briggs, G. M., J. Nutr. **51**, 341 (1953).
7. Mills, C. F., "Trace Element Metabolism in Animals." E. and S. Livingston, Edinburgh (1970).
8. King, C. G., Nutr. Rev. **26**, 33 (1968).
9. Kaiser, J. A., Fed. Proc. **22**, 369 (1963).
10. Figueroa, R., Weiss, R., Smith, J. C., Jr., Hackley, B. M., McBean, L. D., Swassing, C. R., and Halsted, J. A., Amer. Rev. Resp. Dis. **103**, (1971).

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