Iron, Zinc, and Copper Metabolism of Human Subjects Fed Nitrite and Erythorbate Cured Meats

J. L. Greger,* Ken Lee, Karen L. Graham, Barbara L. Chinn, and Janet C. Liebert

Nine adult males consumed a constant mixed diet containing 200 g of processed meat for 51 days. The processed meats fed were uncured sausage (uncured), sausage cured with nitrite (156 μg of nitrite/g of meat) (+N), and sausage cured with nitrite (156 μg of nitrite/g of meat) and erythorbate (550 μg of erythorbate/g of meat) (+E+N). Sausage +E+N was typical of commercial formulations. The dietary treatments had no significant effects on apparent absorption of iron, zinc, or copper, serum zinc or copper levels, or plasma ferritin, transferrin, and ceruloplasmin levels. It is unlikely that commercial curing processes adversely affect the bioavailability of minerals in the meat.

We studied the effects of nitrite curing of meat on the bioavailability of iron, zinc, and copper to human subjects for several reasons. First, approximately one-third of all meat consumed in the United States is cured with nitrite (Goyan and Foreman, 1980). Second, meat products are a major source of dietary zinc and iron for many Americans. Approximately 34% of the iron consumed by Americans participating in the Nationwide Food Consumption Survey was supplied by meat, fish, and poultry products (Science and Education Administration, 1980). Welsh and Marston (1982) estimated that meat, fish, and poultry provided 45% of the zinc in the diets of Americans in 1980. Third, it is well established that iron intake is low and iron-deficiency anemia is fairly common in some segments of our population, i.e., young women and children (National Center for Health Statistics, 1974; Science and Education Administration, 1980). A number of investigators have noted that the zinc and copper intakes of some Americans may be less than optimal (Hambidge et al., 1976; Klevay et al., 1979; Sandstead, 1973; Sandstead et al., 1982).

When individuals consume only marginally adequate levels of a mineral, factors that affect the bioavailability of the mineral assume more practical significance. Several investigators have noted that nitrite affected the regeneration of hemoglobin by rats fed meat or isolated hemoglobin. Park et al. (1983) showed that rats regenerated hemoglobin 25% and 10% less efficiently when fed nitrosylated purified beef and pork hemoglobin, respectively, rather than untreated hemoglobin. Mahoney et al. (1979) fed rats bologna cured with varying levels of nitrite. The results were inconsistent but some levels of nitrite (25, 50, 200, and 400 μg of added nitrite/g of bologna) resulted in less efficient hemoglobin regeneration by rats fed the bologna. van Logten et al (1972) noted that male rats fed a diet containing 40% nitrite-cured meat had reduced erythrocyte counts after 12 and 51 weeks.

One group of investigators indirectly examined the effect of nitrite curing of meat on the bioavailability of copper in meat. Moore et al. (1964) observed that the anemia induced by feeding rats raw meat could be prevented if the meat was cooked or copper salts were added to the diet. However, rats fed corned beef, which was treated with nitrites and commercially processes, became anemic.

There are no reports on the effect of nitrite curing of meats on the bioavailability of iron to human subjects (Committee on Nitrite and Alternative Curing Agents in Food, 1981). It cannot be assumed that nitrite curing will have the same effects on the bioavailability of heme iron in humans and rats because the mechanisms of absorption of heme iron may not be the same in all species (Conrad et al., 1967; Weintraub et al., 1965; Wheby and Spyker, 1981).

When meat is cured commercially in the United States, erythorbate is often added (Mirvish et al., 1972). Erythorbate is an isomer of ascorbate; it has only about 5% of the antiscorbutic activity of ascorbic acid (Goldman et al., 1981). There are no published reports on effects of erythorbate on mineral bioavailability. However, it is well established that human subjects absorb iron more efficiently when ascorbic acid is added to meals (Hallberg and Rossander, 1982; Monsen et al., 1978). Ascorbic acid adversely affects the utilization of copper (Carlton and Henderson, 1965; Finley and Cerklewski, 1983; Smith and Bidlack, 1980; Van Campen and Gross, 1968) and has no effect on zinc absorption (Solomons et al., 1979).

The purpose of this study was to assess the effect of commercial meat curing processes with nitrite and erythorbate on the utilization of iron, zinc, and copper by human subjects.

EXPERIMENTAL PROCEDURES

Experimental Design. Nine subjects participated in this 51-day metabolic study. Subjects consumed the same mixed diet daily throughout the study except that the type of sausage fed during each experimental treatment was different. The types of sausage were a sausage processed without nitrite or erythorbate (uncured), a sausage cured with nitrite only (+N), and a sausage cured with nitrite and erythorbate (+E+N). The sausages were provided in 100-g servings at both lunch and supper daily.

Three subjects were assigned to each treatment during each 17-day experimental period. All subjects participated in all three treatments. Each experimental period consisted of a 5-day adjustment period, two 5-day collection periods (A and B), and a final 2-day period that allowed for complete fecal sample collection.

Subjects. Nine men between 21 and 27 years of age participated in the study. Each subject gave informed consent in a manner approved by a University of Wisconsin committee on the use of human subjects. All subjects were healthy as determined by reported medical histories and examinations by a physician prior to and upon completion of the study. Their mean height was 180 ± 2 (SEM) cm; their mean weight was 78 ± 2 kg at the beginning of the study and was 78 ± 3 kg at the end of the study.

The men were required to eat their breakfast, lunch, and supper at the metabolic facility during specified periods under supervision. They were required to eat all of the

Departments of Nutritional Sciences and Food Science, University of Wisconsin, Madison, Wisconsin 53706.

0021-8561/84/1432-0861$01.50/0

Table I. Analyzed Mineral Content of the Basal Diet and the Average Mineral Intake of Subjects

	analyzed basal diet[b]	average intakes of subjects[a] uncured diet	+N diet	+E+N diet
iron, mg/day	15.29 ± 0.35[c]	18.3	18.1	18.5
zinc, mg/day	9.94 ± 0.16	14.6[d]	14.2[d]	16.1[d]
copper, mg/day	1.17 ± 0.05	1.56	1.58	1.57
nitrogen, g/day	10.2 ± 0.1	14.5	14.9	14.5
sodium, g/day	2.09 ± 0.02	4.48	4.50	4.50
phosphorus, g/day	1.24 ± 0.01	1.46	1.49	1.45
calcium, mg/day	760 ± 3	788	788	789
magnesium, mg/day	300 ± 5	331	334	332
manganese, mg/day	4.62 ± 0.05	4.70	4.75	4.72

[a] Average intake = intake of subjects from basal diet, sausage, mineral supplements, and caloric supplements. [b] Basal diet includes all foods listed in text except sausage. [c] Mean ± SEM (n = 6 composites). [d] 2 mg of zinc intake from zinc acetate supplement.

food provided. They were also required to rinse plates and cups and drink the wash water to prevent loss of food. Distilled water was provided ad libitum for drinking and brushing teeth. Toothpaste was also provided. They were also required to weigh themselves daily before breakfast. Subjects maintained their regular academic and physical routines during the study but refrained from additional physical activities.

Diets. The foods served daily besides the 200 g of cured meats were 0.4 g of pepper, 28 g of shortbread cookies, 30 g of frozen snow peas, 30 g of canned cheese topping, 35 g of potato chips, 40 g of dried potato flakes prepared with 60 g of light whipping cream, 50 g of Shredded Wheat cereal, 50 g of margarine, 50 g of enriched dry rice, 60 g of pound cake, 60 g of frozen onions, 100 g of bottled tomato juice, 100 g of frozen peas, 112 g of ice cream (10% fat), 120 g of enriched French bread, 150 g of frozen blueberries, 200 g of bottled apple juice, 200 g of lemonade made from frozen concentrate, 200 g of noncarbonated soft drink, 244 g of whole milk, and 280 g of lemon carbonated beverage. Each serving of food was weighed to the nearest 0.1 g, except ice cream, cookies, potato chips, lemon carbonated beverage, and pepper, which were purchased in prepackaged servings.

The diet was calculated to supply about 3500 kcal daily. Amounts of margarine, sugar, lemon carbonated beverage, potato chips, cookies, and pound cake in the diet were adjusted so each subject maintained constant weight. The diets were calculated to supply 100% of the recommended dietary allowances (RDA) for protein, phosphorus, iron, calcium, vitamins A and C, thiamin, riboflavin, and niacin (Food and Nutrition Board, 1980). The level of zinc supplied by the basal diet was thought to be less than the recommended dietary allowance; thus a total of 2.0 mg of zinc as zinc acetate in solution was added to the lemonade and to the noncarbonated soft drink served during lunch and supper. A 400-IU supplement of vitamin D was provided daily at breakfast.

Foods were purchased for the entire study in case lots to ensure uniformity. Distilled water was used for cooking. All foods were stored, prepared, and served with plastic and paper containers and utensils to help prevent trace element contamination.

Composites of a total day's food (except for sausage and caloric supplements) were prepared once each week throughout the study. The six food composites, the three types of sausages, and all caloric supplements were analyzed for their mineral content (Table I). The total intakes of subjects were calculated by adding the intake from the basal diet, the cured sausages, and the caloric supplements.

Table II. Contribution of Sausage to Dietary Intakes of Subjects

	% of total intake		
	uncured diet	+N diet	+E+N diet
iron	16	14	17
zinc	32	29	38
copper	19	20	20
nitrogen	4.2	4.5	4.3
sodium	44	43	44
phosphorus	16	17	15
calcium	2.4	2.2	2.7
magnesium	8.2	8.1	7.8
manganese	1.7	1.5	1.7

The percentage of the total nutrient intakes provided by the sausages are listed in Table II.

Sausage Production. The sausages, bologna-type meat emulsions, were produced in the pilot plant of the Meat and Animal Science Department at the University of Wisconsin (Komarik et al., 1974; Lee et al., 1984a). The only difference between the three types of sausage produced for this study was in the curing agents used. The uncured sausage was formulated without erythorbate or nitrite. Nitrite (156 mg of nitrite/kg of sausage) was added to the +N and +E+N sausages. Erythorbate (550 mg of sodium erythorbate/kg of sausage) was added to the +E+N sausage. The +E+N sausage was typical of commercial bologna formulations.

After the sausages were produced, they were divided into 100-g serving units, sealed in Curlon 550 (nylon/Saran/Surlin laminate film), frozen rapidly in a cryogenic freezer, and stored at −40 °C. Although these procedures reduced the rate of loss of nitrite and erythorbate from the sausage during storage (Cassens et al., 1979), they did not prevent all losses. At the initiation of the metabolic study the +N sausage contained 49 mg of nitrites/kg of sausage; the +E+N sausage contained 47 mg of nitrite and 200 mg of erythorbate per kg of sausage (Lee and Shimaoka, 1984b). These levels are comparable to those found in commercial products that have been stored only a short time (Cassens et al., 1979).

Chemical Analyses. All fecal urine and food samples were collected and stored in acid-washed plastic containers. Brilliant blue dye was administered to subjects before breakfast on days 6, 11, and 16 of each 17-day treatment period. Fecal composites were prepared accordingly. Urine composites for individual subjects were prepared daily, acidified to be a 0.5% nitric acid solution, and frozen. Five-day urine composites for days 6–10 and days 11–15 of each treatment period were prepared from the daily urine composites. Venous blood samples were collected from subjects before breakfast on day 1 of the study and on days 10 and 15 of each treatment period with specially treated Vacutainer tubes that were designed for use when zinc levels are to be determined (Becton-Dickinson and Co., Rutherford, NJ).

Food and fecal composites were homogenized in stainless steel blenders. Aliquots of deionized water that were homogenized in these blenders before preparation of composites contained no detectable levels of iron, zinc, and copper.

Portions of food and fecal samples were heated in a muffle oven at 450 °C (Hegsted et al., 1981) and analyzed for iron, zinc, copper, sodium (food only), and calcium (food only) by atomic absorption spectroscopy and for phosphorus by a colorimetric procedure (Fiske and Subbarow, 1925). Samples of bovine liver standard, which was obtained from the National Bureau of Standards, were prepared with each batch of samples. Liver samples (n

Table III. Intake, Excretion, and Apparent Retention of Iron, Zinc, and Copper by Subjects Fed Sausages Cured with and without Nitrite (N) and Erythorbate (E)

	treatments		
	uncured	+N	+E+N
iron			
intake, mg/day	18.3 ± 0.3[a]	18.1 ± 0.3	18.5 ± 0.4
fecal loss, mg/day	17.1 ± 0.5	15.7 ± 0.1	17.4 ± 0.7
apparent absorption, %	6.4 ± 2.1	13.0 ± 2.8	5.9 ± 3.4
urinary loss: mg/kg	0.35 ± 0.02	0.36 ± 0.01	0.37 ± 0.01
mg/g of creatinine	0.20 ± 0.01	0.20 ± 0.01	0.21 ± 0.01
apparent retention,[b] mg/day	0.8 ± 0.4	2.0 ± 0.5	0.7 ± 0.7
zinc			
intake, mg/day[c]	14.6 ± 0.2[a]	14.2 ± 0.2[a]	16.1 ± 0.2[b]
fecal loss, mg/day[c]	13.6 ± 0.3[ab]	12.2 ± 0.6[a]	15.0 ± 0.7[b]
apparent absorption, %	6.9 ± 2.2	13.1 ± 3.7	6.5 ± 4.2
urinary loss: mg/day	0.70 ± 0.05	0.70 ± 0.08	0.67 ± 0.08
mg/g of creatinine	0.39 ± 0.03	0.40 ± 0.04	0.37 ± 0.05
apparent retention,[b] mg/day	0.3 ± 0.3	1.2 ± 0.1	0.4 ± 0.7
copper			
intake, mg/day	1.56 ± 0.03	1.58 ± 0.04	1.57 ± 0.04
fecal loss, mg/day	1.11 ± 0.06	1.07 ± 0.05	1.16 ± 0.06
apparent absorption, %	28.3 ± 3.7	32.1 ± 3.1	26.3 ± 2.7
urinary loss: μg/day	60 ± 3	64 ± 3	60 ± 3
μg/g of creatinine	33 ± 2	36 ± 2	33 ± 2
apparent retention,[b] mg/day	0.38 ± 0.06	0.45 ± 0.05	0.35 ± 0.04

[a] Mean ± SEM (n = 9 subjects). [b] Apparent retention = intake − fecal loss − urinary loss. [c] Means in row with different superscripts are significantly different at the $p < 0.01$ level.

Table IV. Hematological Indices of Nutritional Status with Regard To Iron, Zinc, and Copper among Subjects Fed Sausages Cured with and without Nitrite (N) and Erythorbate (E)

		treatments					
		uncured		+N		+E+N	
	prior to treatment	period A	period B	period A	period B	period A	period B
hematocrit, %	45 ± 1[a]	46 ± 1	45 ± 1	46 ± 1	45 ± 1	46 ± 1	47 ± 1
plasma transferrin, mg/dL	274 ± 12	280 ± 17	272 ± 10	292 ± 12	273 ± 14	266 ± 14	299 ± 14
plasma ferritin, ng/mL	94 ± 23	90 ± 22	87 ± 24	88 ± 24	80 ± 19	82 ± 21	83 ± 21
serum zinc, μg/dL	99 ± 3	108 ± 3	108 ± 2	113 ± 5	109 ± 3	113 ± 3	112 ± 4
serum copper, μg/dL	79 ± 4	80 ± 4	78 ± 4	78 ± 2	78 ± 3	79 ± 2	79 ± 2
plasma ceruloplasmin, mg/dL	23 ± 2	23 ± 1	23 ± 1	24 ± 1	22 ± 1	23 ± 1	23 ± 1

[a] Mean ± SEM (n = 9).

≥ 36) were determined to contain on the average 96%, 102%, and 102% of the certified amounts of iron, copper, and zinc, respectively.

The zinc, copper, and iron content of urine and plasma samples were determined by atomic absorption spectroscopy with procedures described previously (Greger and Snedeker, 1980). The creatinine content of fresh urine samples were determined daily by an alkaline–picrate method (Peters, 1942).

Serum samples were diluted 1:1 (v/v) with deionized water before zinc and copper levels were determined by atomic absorption spectroscopy. Standards were prepared with glycerin so that flow rates of standards equaled the flow rates of the diluted samples. When known amounts of zinc and copper were added to plasma samples processed in this manner, recoveries (n = 6) averaged 100% for both elements. Plasma ceruloplasmin and transferrin levels were determined with prepared radial immunodiffusion plates (Behring Diagnostics, Americal Hoechst Corp., Somerville, NJ) (Mancini et al., 1965). Plasma ferritin levels were assayed by a radioimmunoassay (Gamma Dab ^{125}I-ferritin radioimmunoassay kit, Clinical Assays, Cambridge, MA). Hematocrits were determined with microcapillary tubes.

Statistical Analyses. The effects of the dietary treatments on the variables measured were evaluated by computer with analysis of variance (Ryan et al., 1976). Means were then compared with tests of least significant differences (Steel and Torrie, 1960).

RESULTS

No differences were noted in the data collected during replicate periods A (days 6–10) and B (days 11–15) of each experimental period; thus, the excretion and retention of minerals during each of the experimental periods were reported as averages for the entire 10 days of sample collection (Table III).

The sausages fed in this study provided 14–17% of subjects' daily iron intakes (Table II). In general, the iron intakes of subjects were high (>180% of the RDA for adult males). However, sausage was the only source of heme iron in the diet. Approximately 50–60% of the iron in beef is believed to be heme iron (Monsen et al., 1978); the subjects accordingly consumed 1.3–1.9 mg of heme iron daily.

Curing the sausages with nitrite and erythorbate had no apparent effect on the intake, excretion, or apparent retention of dietary iron (Table III). Subjects tended to lose less iron in their feces when fed the sausage processed with nitrite only (+N), but this difference was not statistically significant.

The dietary treatments also had no effects on any of the hematological variables used to monitor nutritional status with regard to iron among the subjects (Table IV).

Hematocrits of subjects ranged from 41% to 49%. All were within a normal range (National Center for Health Statistics, 1974). Plasma transferrin levels ranged from

221 to 391 mg/dL. Only one subject had plasma transferrin levels above 350 mg/dL. Normal levels of transferin in plasma are not well defined but all the values appear to be within a normal range (200–400 mg/dL) (Schultz and Heremans, 1966). Plasma ferritin levels ranged from 4 to 256 ng/mL. Only one subject had plasma ferritin levels of <12 ng/mL and could be considered to be iron depleted (Cook and Finch, 1979). The plasma ferritin levels of the remaining subjects ranged from 26 to 256 ng/mL. The subject with the low plasma ferritin levels was also the subject with the high plasma transferrin levels. However, this subject did not have the lowest hemotocrit levels in this group; his hematocrit ranged from 47% to 48%.

The standard errors of means in Table IV for plasma ferritin levels are large. They reflect large intersubject not intrasubject variation. The coefficients of variation on plasma ferritin levels for individual subjects (n = 7 blood collections) ranged from 2% to 12%.

The sausages were rich sources of zinc and provided almost one-third of the zinc consumed by subjects daily (Table II). The subjects consumed approximately the RDA for zinc during this study. Although the three types of sausages were processed together, the sausage cured with erythorbate and nitrite (+E+N) contained more zinc than the other two. Thus subjects consumed significantly ($p < 0.01$) more zinc daily when fed sausage +E+N than when fed the uncured or +N sausages.

The subjects lost significantly ($p < 0.01$) less zinc in their feces when fed sausage +N than when fed sausage +E+N (Table III). Although subjects consumed more zinc when fed +E+N sausage than when fed uncured sausage, they apparently absorbed similar percentage of their zinc intakes. However, when fed the +N sausage, subjects absorbed a larger percentage of their zinc intake and retained somewhat more zinc daily than during the other two treatment periods; these differences were not statistically significant.

Urinary zinc losses and plasma zinc levels were unaffected by the dietary treatments. Plasma zinc levels ranged from 90 to 125 μg/dL and were all within a normal range (>70 μg/dL).

The subjects' intake of copper during this study was less than the amount (2–3 mg) suggested by the Food and Nutrition Board to be safe and adequate (Food and Nutrition Board, 1980). However, the copper intakes of the subjects were typical of those of many Americans (Klevay et al., 1979). Furthermore, all subjects appeared to be in positive balance in regard to copper during this study. However, sweat losses were not monitored.

The sausages contributed about one-fifth of the copper in the sujects' diets. The differences in the sausages had no apparent effects on the excretion or retention of copper by the subjects.

Serum copper and plasma ceruloplasmin levels were also unaffected by the dietary treatments. Subjects' serum copper levels ranged from 63 to 105 μg/dL. Two subjects could be considered to be in marginal status with regard to copper (<70 μg/dL) (American Dietetics Association, 1981). In our laboratory we have observed on several occasions that young male subjects in Wisconsin often have low (<70 μg/dL) plasma copper levels (Greger and Baier, 1983; Johnson et al., 1982; Snedeker and Greger, 1981). The absorption and excretion of copper by these subjects were similar to those with normal serum copper levels. Plasma cerruloplasmin levels ranged from 16 to 32 mg/dL; they were somewhat below the average ceruloplasmin levels reported elsewhere (American Dietetics Association, 1981). As would be expected, those subjects with low (<70 μg/dL) serum copper levels also had low (<20 μg/dL) plasma cerruloplasmin levels. Each subject's serum copper and plasma ceruloplasmin levels remained constant throughout the study; there was no decline associated with length of participation in the study. Thus, the level of copper fed to the subjects could be judged to have no adverse effect on the subjects' nutritional status with regard to copper and/or it could be assumed that copper intakes of subjects were typically in this range.

DISCUSSION

The average American participating in the 1977 Nationwide Food Consumption Survey consumed 207 g of meat, fish, and poultry per day; the average adult male (23–34 years of age) in this survey consumed 285 g of meat, fish, and poultry daily (Science and Education Administration, 1980). We fed our subjects 200 g of cured meat daily. Generally, about one-third of the meat consumed by Americans is cured (Goyan and Foreman, 1980). Thus, our subjects consumed 2–3 times as much cured meat daily as the average American. Consumption of this amount of meat cured with commercially acceptable levels of nitrite and erythorbate had no adverse effect on the metabolism of iron, zinc, and copper of adult males.

We know of no other studies in which the effects of nitrite and erythorbate curing of meat on the bioavailability of minerals in the meat were evaluated with human subjects (Committee on Nitrite and Alternative Curing Agents in Food, 1981). Our results are consistent with the data collected in an iron repletion study with rats that was run concurrently with this human study (Lee et al., 1984b). Sausage fed in both of these studies was from the same batch. In both studies the addition of cured meat to the diet was not found to adversely affect the bioavailability of iron from the diet.

Similarly van Logten et al. (1972) observed that the addition of nitrite cured meat to the diets of rats had few effects on hematological indices. Only one was significant; male rats fed the nitrite-cured meat for 12 and 51 weeks had reduced erythorbate counts.

Park et al. (1983) observed that anemic rats used the iron in purified hemoglobin less efficiently when it was nitrosylated. However, Hazell et al. (1978, 1981) have noted that nitrosylated purified hemoglobin may not exert the same effects on biological systems as cured meat because the purification process alters the integrity of the heme proteins.

Mahoney et al. (1979) observed that anemic rats generally utilized the iron in bologna less efficiently when the meat had been processed with nitrite. However, they observed that the addition of 12 μg/g nitrite to bologna- and casein-based diets increased the hematinic response of rats. The differences in data from this study by Mahoney et al. and our study with human subjects may be due to species differences, differences in the processing and storage of meat (our cured meat retained higher levels of nitrite even though it was generally processed with less nitrite), or differences in the iron status of the animals (subjects, with one exception, were not iron depleted; their rats were very anemic).

We observed that the use of erythorbate at commercially acceptable levels in sausage had no effect on the utilization of iron, copper, and zinc by our subjects. Ascorbate, an isomer of erythorbate, improves the absorption of nonheme iron (Monsen, 1982), tends to depress the utilization of copper (Carlton and Henderson, 1965; Smith and Bidlack, 1980; Van Campen and Gross, 1968), and exerts no direct effect on zinc metabolism (Solomons et al., 1979). However, the effects of erythorbate on iron, zinc, and copper

bioavailability have not been reported.

This study was not designed to examine whether erythorbate (at any levels) could influence mineral bioavailability. Our subjects consumed about 22 mg of erythorbate with both lunch and dinner when they consumed 100 g of the +E+N sausage with each meal. Each of these meals contained about 40 mg of ascorbate from other foods. High levels of ascorbate, about 1% of the total diet, were fed to animals in the studies in which depression of copper utilization was noted (Van Campen and Gross, 1968). According to the model by Monsen et al. (1978), the amount of meat in each meal was sufficient to ensure high bioavailability of the iron in the meal. Thus, it may be unrealistic to expect additional erythorbate, or even additional ascorbate, could improve iron bioavailability further. However, Monsen (1982) has suggested ascorbate over a wide range of intakes can influence iron bioavailability. We cannot on the basis of this study evaluate whether erythorbate could influence copper and iron utilization in some situations (i.e., when high levels of erythorbate are fed and no meat factor, heme iron, or ascorbate is fed). However, we conclude that the addition of erythorbate to the cure mixture as is now common practice in the United States is unlikely to influence the utilization of minerals by human subjects.

ACKNOWLEDGMENT

We appreciate the cooperation of Robert G. Cassens and James V. Lochner of the Meat and Animal Science Department, University of Wisconsin–Madison, and of the nine subjects.

Registry No. Erythorbate, 89-65-6; nitrite, 14797-65-0; ceruloplasmin, 9031-37-2; copper, 7440-50-8; zinc, 7440-66-6; iron, 7439-89-6.

LITERATURE CITED

American Dietetics Association. "Handbook of Clinical Dietetics"; Yale University Press: New Haven, CT, 1981; p 120.
Carlton, W. W.; Henderson, W. *J. Nutr.* **1965**, *85*, 67.
Cassens, R. G.; Greaser, M. L.; Ito, T.; Lee, M. *Food Technol. (Chicago)* **1979**, *33*, 46.
Committee on Nitrite and Alternative Curing Agents in Food. "The Health Effects of Nitrate, Nitrite and N-Nitroso Compounds"; National Academy Press: Washington, DC, 1981.
Conrad, M. E.; Benjamin, B, I,; Williams, H. L.; Foy, A. L. *Gastroenterology* **1967**, *53*, 5.
Cook, J. D.; Finch, C. A. *Am. J. Clin. Nutr.* **1979**, *32*, 2115.
Finley, E. B.; Cerkewski, F. L. *Am. J. Clin. Nutr.* **1983**, *37*, 553.
Fiske, C. H.; Subbarow, Y. *J. Biol. Chem.* **1925**, *66*, 375.
Food and Nutrition Board. "Recommended Dietary Allowances"; National Academy of Sciences: Washington, DC, 1980.
Goldman, H. M.; Gould, B. S.; Munro, H. N. *Am. J. Clin. Nutr.* **1981**, *34*, 24.
Goyan, J. E.; Foreman, C. T. "HHS News"; U.S. Department of Health and Human Services: Washington, DC, 1980; Aug 19.
Greger, J. L.; Baier, M. J. *Am. J. Clin. Nutr.* **1983**, *38*, 411.
Greger, J. L.; Snedeker, S. M. *J. Nutr.* **1980**, *110*, 2243.
Hallberg, L.; Rossander, L. *Am. J. Clin. Nutr.* **1982**, *35*, 502.
Hambidge, k. M.; Walravens, P. A.; Brown, R. M.; Webster, J.; White, S.; Anthony, M.; Roth, M. L. *Am. J. Clin. Nutr.* **1976**, *29*, 734.
Hazell, T.; Ledward, D. A.; Neale, R. J. *Br. J. Nutr.* **1978**, *39*, 631.
Hazell, T.; Ledward, D. A.; Neale, R. J.; Root, I. C. *Meat Sci.* **1981**, *5*, 397.
Hegsted, M.; Schuette, S. A.; Zemel, M. B.; Linkswiler, H. *J. Nutr.* **1981**, *111*, 553.
Johnson, M. A.; Baier, M. J.; Greger, J. L. *Am. J. Clin. Nutr.* **1982**, *35*, 1332.
Klevay, L. M.; Reck, S. J.; Barcome, D. F. *JAMA, J. Am. Med. Assoc.* **1979**, *241*, 1916.
Komarik, S. L.; Wessler, D. K.; Long, L. "Food Products Formulary"; Avi Publishing Co.: Westport, CT, 1974; Vol. 1, p 51.
Lee, K.; Chinn, B. A.; Greger, J. L.; Graham, K. L.; Liebert, J. C. *J. Agric. Food. Chem.* **1984**, preceding paper in this issue.
Lee, K.; Shimoaka, J. E.; *J. Food Sci.* **1984b**, in press.
Mahoney, A. W.; Hendricks, D. G.; Gillett, T. A.; Buck, D. R.; Miller, C. G. *J. Nutr.* **1979**, *109*, 2182.
Mancini, G.; Carbonara, A. O.; Heremans, J. F. *Immunochemistry* **1965**, *2*, 235.
Mirvish, S. S.; Wallcare, L.; Egan, M.; Shubik, P. *Science (Washington, D.C.)* **1972**, *177*, 65.
Monsen, E. R. "Nutritional Bioavailability of Iron"; American Chemical Society: Washington, DC, 1982; p 85.
Monsen, E. R.; Hallberg, L.; Layrisse, M.; Hegsted, D. M.; Cook, J. D.; Mertz, W.; Finch, C. A. *Am. J. Clin. Nutr.* **1978**, *31*, 134.
Moore, T.; Constable, B. J.; Day, K. C.; Impey, S. G.; Symonds, K. R. *Br. J. Nutr.* **1964**, *18*, 135.
National Center for Health Statistics. *DHEW Publ. (HRA) (U.S.)* **1974**, *HRA 74-1219-1*.
Park. Y. W.; Mahoney, A. W.; Cornforth, D. P.; Collinge, S. K.; Hendricks, D. G. *J. Nutr.* **1983**, *113*, 680.
Peters, J. H. *J. Biol. Chem.* **1942**, *146*, 179.
Ryan, T. A.; Joiner, B. L.; Ryan, B. F. "Minitab Student Handbook"; Duxbury Press: North Scituate, MA, 1976.
Sandstead, H. H. *Am. J. Clin. Nutr.* **1973**, *26*, 1251.
Sandstead, H. H.; Henriksen, L. K.; Greger, J. L.; Prasad, A. S.; Good, R. A. *Am. J. Clin. Nutr.* **1982**, *36*, 1046.
Schultz, H. E.; Heremans, J. F. "Molecular Biology of Human Proteins"; Elsevier: New York, 1966; Vol. I.
Science and Education Administration. "Food and Nutrient Intakes of Individuals in 1 Day in the United States, Spring 1977"; Nationwide Food Consumption Survey, U. S. Department of Agriculture: Washington, DC, 1980; Preliminary Report No. 2.
Smith, C.; Bidlack, W. *J. Nutr.* **1980**, *110*, 1398.
Snedeker, S. M.; Greger, J. L. *Nutr. Rep. Int.* **1981**, *23*, 853.
Solomons, N. W.; Jacob, R. A.; Pineda, O.; Viten, F. E. *Am. J. Clin. Nutr.* **1979**, *32*, 2495.
Steel, R. G. D.; Torrie, H. J. "Principles and Procedures of Statistics"; McGraw-Hill: New York, 1960.
Van Campen, D.; Gross, E. *J. Nutr.* **1968**, *95*, 617.
van Logten, M. J.; den Tonkelaar, E. M.; Kroes, R.; Berkvens, J. M.; van Esch, G. J. *Food Cosmet. Toxicol.* **1972**, *10*, 475.
Weintraub, L. R.; Conrad, M. E.; Crosby, W. H. *Proc. Soc. Exp. Biol. Med.* **1965**, *120*, 840.
Welsh, S. O.; Marston, R. M. *Food Technol. (Chicago)* **1982**, *36*, 70.
Whelby, M. S.; Spyker, D. A. *Am. J. Clin. Nutr.* **1981**, *34*, 1686.

Received for review October 11, 1983. Accepted January 25, 1984. This research was supported by the College of Agricultural and Life Sciences, University of Wisconsin—Madison, WI, Projects 2577 and 2617, the National Livestock and Meat Board, and the Food Research Institute.