Nutrient Physiology, Metabolism, and Nutrient-Nutrient Interactions

Demonstrating Zinc and Iron Bioavailability from Intrinsically Labeled Microencapsulated Ferrous Fumarate and Zinc Gluconate Sprinkles in Young Children

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ABSTRACT Nutrient-nutrient interactions are an important consideration for any multiple-micronutrient formulation, including Sprinkles, a home-fortification strategy to control anemia. The objectives of this randomized controlled trial were as follows: 1) to compare the absorption of zinc at 2 doses given as Sprinkles; and 2) to examine the effect of zinc and ascorbic acid (AA) on iron absorption from Sprinkles. Seventy-five children aged 12–24 mo were randomly assigned to the following groups: 1) 5 mg of labeled zinc (Zn) with 50 mg AA (LoZn group); b) 10 mg of labeled zinc (Zn) with 50 mg AA (HiZn group); or c) 5 mg zinc with no AA (control). All groups contained 30 mg of labeled iron (Fe). Intravenous infusions labeled with Zn (LoZn and HiZn groups) and Fe (control) were administered. Blood was drawn at baseline, 48 h and 14 d later. The percentage of zinc absorbed did not differ between LoZn (geometric mean = 6.4%; min-max: 1.7–14.6) and HiZn (geometric mean = 7.5%; min-max: 3.3–18.0) groups. However, total zinc absorbed was significantly different between the LoZn (geometric mean = 0.31 mg; min-max: 0.08–0.73) and HiZn (geometric mean = 0.82 mg; min-max: 0.33–1.82) groups (P = 0.0004). Geometric mean percentage iron absorption values did not differ between the LoZn (5.9%; min-max: 0.8–21) and HiZn (4.4%; min-max: 0.6–12.3) groups and between the LoZn and control groups (5.0%; min-max: 1.4–24). We conclude that zinc in the form of Sprinkles has a low bioavailability, yet provides adequate amounts of absorbed zinc in young children, and that there is no effect of zinc or AA on iron absorption from the given formulations of Sprinkles. J. Nutr. 136: 920–925, 2006.

KEY WORDS: • home-fortification • stable isotopes • zinc absorption • iron absorption • Sprinkles

In recent years, it has become evident that young children 6–24 mo of age comprise a high-risk group for concurrent iron and zinc deficiencies in most developing countries (1). Home-fortification is a new approach to improve the micronutrient content of complementary foods. Single-dose sachets (called Sprinkles) containing micronutrients in powdered form (including microencapsulated iron, zinc, vitamin A, folic acid, and ascorbic acid) are easily added to foods prepared in the household just before serving (2). Using dual stable isotopes and intrinsically labeled microencapsulated ferrous fumarate, we recently demonstrated that iron absorption is twice as high in children with iron deficiency anemia than in nonanemic children (3). Notwithstanding these positive results, an important unanswered question is the effect of the concurrent ingestion of both iron and zinc (in Sprinkles) and their interaction. Due to the potential negative effect on micronutrient status from minerals that are competing for absorption, ensuring that both iron and zinc are bioavailable merits particular attention (4). Also of interest is the effect of ascorbic acid on the absorption of iron from Sprinkles. Ascorbic acid was shown to have a dose-dependent enhancing effect on nonheme iron absorption (5). Yet, reports in the literature suggest that ascorbic acid may not enhance the absorption of iron from foods fortified with ferrous fumarate (6,7).
The study reported here investigated the concurrent absorption of zinc and iron from Sprinkles when added to a maize-based complementary food, in a mixed population of anemic and nonanemic young children. Using stable isotope techniques, our primary objective was to determine whether there was a difference in the absorption of zinc at 2 different doses given as Sprinkles. Our secondary objective was to examine whether zinc and ascorbic acid have an effect on the absorption of iron from Sprinkles.

SUBJECTS AND METHODS

Study area, participants, and recruitment

The study was conducted from June to September 2002 in the field study area for the Kintampo Health Research Centre located in the Kintampo district of Ghana. The study protocol was approved by the Research Ethics Committees at the Hospital for Sick Children (Toronto, Canada), and Ghana Health Service Ethics Review Board (Accra, Ghana). Verbal consent to conduct the study in the Kintampo district was obtained from opinion leaders within the Kintampo District. Written informed consent was obtained individually from the mothers of the children before the start of the study.

To be included, children were required to be between 12 and 24 mo of age, be ingesting at least one complementary food in addition to breast milk, be free from major illness such as symptomatic malaria, be afebrile, have a hemoglobin (Hb) concentration ≥7.0 g/L and be able to stay within the study area for the study period. Children found to be febrile or severely anemic (Hb < 7.0 g/L) were treated at no personal expense.

Study design and protocol

Eligible children were studied at the Kintampo Health Research Centre on the mornings of d 1, 2, 3, and 17. Randomization was done by using coded chips pulled from an opaque bag by the child’s mother. Children were randomized as follows. 1) Low zinc (LoZn) group: 5 mg of elemental zinc as 67Zn-labeled zinc gluconate, combined with 50 mg ascorbic acid (AA) and 30 mg of elemental iron as 57Fe-labeled microencapsulated ferrous fumarate; 2) high zinc (HiZn) group: 10 mg of elemental zinc as 67Zn-labeled zinc gluconate, combined with 50 mg AA and 30 mg of elemental iron as 57Fe-labeled microencapsulated ferrous fumarate; or 3) no ascorbic acid (control) group: 5 mg elemental zinc as zinc gluconate (standard food-grade) combined with 30 mg of elemental iron as Fe-labeled microencapsulated with no added AA.

Sprinkles in all groups were also formulated with the standard dose of 300 µg retinol equivalents of retinol acetate vitamin A. All doses were individually weighed into color-coded opaque Eppendorf tubes by experienced laboratory personnel at the Hospital for Sick Children (Toronto, Canada). Assignment of the group designation was revealed only upon completion of the statistical analyses.

The higher dose of zinc (10 mg) was based on commonly used dosages of zinc in supplementation trials in developing countries involving young children (8–10). The lower dose of zinc (5 mg) was based on the Recommended Dietary Allowance (11) for zinc in children 12–24 mo of age. The total dose of elemental iron to be tested (30 mg) was based on our previous bioavailability study conducted among a similar population of children in Ghana (3).

After randomization (d 1), Hb was determined in each participant and a heparinized venous blood sample (3 mL) was obtained. Immediately after the blood sample was taken, a 10 mL [67Zn] sulfate (0.5 mg zinc) i.v. infusion was administered through a 1.2-µm filter over 5 min to children in Groups LoZn and HiZn only. Fourteen days later (d 17), Hb was determined and a final blood sample was collected from a finger prick (500 µL) in all groups. Anthropometric measurements, including weight and length, were completed as previously described (12). After exclusion, withdrawal, or completion of the trial, all anemic children (Hb < 100 g/L) were given a 2-mo supply of Sprinkles (12).

Stable isotope labels and dosing

Zinc stable isotopes. Zinc isotopes were purchased from Trace Sciences International as oxide powder ([67Zn] Zn at 82.0% enrichment) and white oxide powder ([65Zn] Zn at 95.56% enrichment). The oral [65Zn] oxide powder was converted to [67Zn] gluconate by one of the major commercial suppliers of zinc fortification compounds, Dr. Paul Lehmann GmbH KG (Emmerthal, Germany). For the preparation of [67Zn] gluconate, [65Zn] oxide was dissolved in demineralized water and glucono-delta-lactone. The mixture was then evaporated until dry. The [67Zn] white oxide powder was then reconstituted with sterile saline to a 70Zn-labeled liquid at a final concentration of 50 mg 70Zn/L at a pH of 4. Subsequently, the solution was filtered through a 0.22-µm filter and stored in individual sterile injection vials (10 mL), which were purged with nitrogen, sealed and kept refrigerated until use. The final solution was tested for sterility and pyrogenicity before use. Total zinc concentration of the final product was determined using inductively coupled plasma MS (Activation Laboratories).

Iron stable isotopes. Details on the iron isotopes ([57Fe and 56Fe] used in this study including their origin, abundances, conversions, microencapsulation of [57Fe]ferrous fumarate, dosages, and validation were described elsewhere (3).

Blood samples

Whole blood samples collected at baseline (d 1) and on d 17 were used to make thick blood smears and determine iron isotopic composition of erythrocytes. At baseline, plasma was used to determine mass isotope zinc ratio (in groups LoZn and HiZn only), zinc concentration, and soluble transferrin receptor concentration (sTfR). On d 3, plasma was used for analysis of 48-h plasma zinc isotope ratios. Hb and sTfR were measured as previously described (3). Malaria smear were examined at the Noguchi Memorial Institute for Medical Research, University of Ghana, Legon, using standard techniques.

Analysis of isotopic composition of blood samples

Zinc isotope analysis. Zinc isotope analysis was completed using methods described by Serfass et al. (13) with minor modifications. The inductively coupled plasma MS instrument (PlasmaQuad 3, TJA Solutions) used to determine the zinc isotopes had the following operating parameters: Plasma power, 1350 W; rest mass, 65.5 amu.; nominal dwell masses, 66.0, 67.0, 70.0 amu; dwell time, 10 ms; points per peak, 3; acquisition time, 18 s; replicate acquisitions, 10; ratios, 67:66, 70:66. A standard solution of yttrium (200 ng/L) in 0.15 mol/L nitric acid was used to optimize the instrumental parameters, to avoid contamination of the instrument with extraneous zinc. The mean relative precision (percentage relative SD, n = 28) obtained for [67Zn]/[66Zn] ratio measurements was 1.18% and for [63Zn]/[66Zn] ratio measurements was 1.22%.

No food or liquids other than water and breast milk were allowed for 4 h before the test meal administration. The test meal used throughout the study was made from locally available foods as previously described (3). All test meals to which the labeled Sprinkles were added were given to the children on 2 consecutive days using the same protocol as previously described (3). Samples from 11 test meals were analyzed for phytic acid and iron; the phytate:iron molar ratio was 9.8 (Health Canada, Ottawa, Canada).

A finger prick blood sample (500 µL) was collected into heparinized Microvette® tubes on d 3 (Sarstedt) from participants in Groups LoZn and HiZn only. The mixture was then evaporated until dry. The [67Zn] white oxide powder was then reconstituted with sterile saline to a 70Zn-labeled liquid at a final concentration of 50 mg 70Zn/L at a pH of 4. Subsequently, the solution was filtered through a 0.22-µm filter and stored in individual sterile injection vials (10 mL), which were purged with nitrogen, sealed and kept refrigerated until use. The final solution was tested for sterility and pyrogenicity before use. Total zinc concentration of the final product was determined using inductively coupled plasma MS (Activation Laboratories).

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6 Abbreviations used: AA, ascorbic acid; DMT1, divalent metal transporter-1; Hb, hemoglobin; HiZn, high zinc group; LoZn, low zinc group; min, minimum; max, maximum; sTfR, soluble transferrin receptor; Zn, zinc.
Iron isotope ratios were measured in the RBC 14 d after administration, as previously described (3). Mean relative precision (percentage relative SD, n = 72) obtained for $^{57}$Fe/$^{58}$Fe ratio measurements was 0.46% and for $^{67}$Fe/$^{68}$Fe ratio measurements was 0.56%.

Calculation of zinc and iron absorption

The percentage of zinc absorption was determined according to O’Brien et al. (14). The degree to which the zinc isotope ratios differed from baseline ratios was determined as follows:

$$\text{Delta percent excess of } \frac{^{67/66}\text{Zn}}{^{65/64}\text{Zn}} = \left(\frac{^{67/66}\text{Zn observed}}{^{65/64}\text{Zn baseline}} - 1\right) \times 100$$

The natural abundance ratios used for the $^{67/66}$Zn and $^{70/66}$Zn isotope ratios were 0.14779 and 0.02229, respectively.

The percentage of zinc absorption was determined by measuring the ratio of the oral to the i.v. zinc label in plasma samples as follows: Percent Zn absorption =

$$\left(\frac{^{67/66}\text{Zn baseline}}{^{66}\text{Zn observed}} \times \frac{^{67/66}\text{Zn delta % excess}}{^{70/66}\text{Zn baseline}} \times (iv^{70}\text{Zn dose}) \times 100.\right)$$

The percentage of iron absorption from the administered dose was calculated as described previously (3).

Sample size. Our sample size estimation was based on our primary objective. Using data from our past work on zinc absorption from infant cereal (unpublished), the SD of the percentage of zinc absorption was estimated to be 4%. Based on an independent t test comparison, we estimated that 17 children per group would have a power of 80% ($\alpha = 0.05$) to reject the null hypothesis that the difference in percentage zinc absorption between LoZn and HiZn groups was zero. The minimal detectable difference was 4%. Assuming a 30% dropout rate, we planned to recruit 22 children per group.

Statistical methods. Continuous data were examined with descriptive statistics (means and SD) and histograms. When data were skewed, log transformation and computed geometric means and ranges were used. Binary data were summarized with frequency counts and percentages. Hb and sTfR concentrations were dichotomized using cut-off levels of <100 g/L (3) and >8.5 mg/L (15,16), for anemia and iron deficiency, respectively. Scatter plots (and correlation coefficients) were used to examine the relation between iron and zinc absorption values by anemia status.

Zinc absorption. Zinc absorption in the LoZn group was compared with that of the HiZn group using a general linear model that had log-transformed zinc absorption as the dependent variable and LoZn group allocation as the independent variable. This model was extended to adjust for any significant differences between groups including age, gender, Hb, plasma zinc, sTfR, and malaria.

Effect of zinc and ascorbic acid on iron absorption. Using similar linear models that had log-transformed iron absorption values as the dependent variable and LoZn group allocation as the independent variable, we compared the LoZn and HiZn groups to test for the effect of zinc on iron absorption, and the LoZn and control groups to test for the effect of AA on iron absorption. Again, we extended the model to test for any potential confounding variables. We used Tukey’s adjustment for multiple comparisons. For all calculations and analyses, we used SAS, version 9.1 (SAS Institute).

RESULTS

Participant characteristics and hematological indices

Seventy-five children were screened and 60 completed the study (Fig. 1). Reasons for exclusion included severe anemia (Hb <70 g/L), fever, and withdrawal. The i.v. infusions could be administered to only 13 children in LoZn group, 15 children in HiZn group, and 12 children in control group because of difficulty in accessing veins in the rest of the participants. With the exception of Hb, the 3 groups did not differ in characteristics and hematological indices (Table 1). The prevalence of iron deficiency varied from 71 to 80% across the 3 groups. The number of children who tested positive for malaria was as follows: 11 in the LoZn group, 4 in the HiZn group, and 7 in the control group.

Zinc absorption

The final concentration of the $^{70}$Zn-labeled i.v. infusion (after filtration) was 43.2 mg/L (86.4% of planned final concentration). Zinc absorption is reported for the LoZn and HiZn groups in which the participants received the i.v. infusion (Table 2). The percentage of zinc absorbed did not differ, whereas the total amount of zinc absorbed (mg) from the 2 doses was significantly different ($P = 0.0004$).
Effect of zinc and ascorbic acid on iron absorption

Information on the validation of the $^{57}$Fe-labeled i.v. infusion administered to the control group and on the calculation of iron absorption was reported elsewhere (3). The percentage and total amount of erythrocyte incorporation of iron or iron absorbed between the LoZn and HiZn groups and between the LoZn and control groups did not differ (Table 2).

Relation between iron and zinc absorption

The plot (Fig. 2) suggests that nonanemic children who absorbed iron at a higher percentage also absorbed zinc at a higher percentage and vice versa ($r = 0.68; P < 0.01$). There was no relation between iron and zinc absorption in anemic children ($r = 0.05; P > 0.05$).

**DISCUSSION**

This study is the first to report the extent to which iron and zinc are concurrently absorbed by young children when added to a maize-based porridge as part of a home-fortification strategy. The study population consisted of both anemic and nonanemic young children most of whom were zinc replete (based on a low prevalence of low plasma zinc concentrations). The percentage of zinc absorption did not differ at the intakes of 5 or 10 mg of zinc and there was no effect of zinc on iron absorption. Similarly, the addition of ascorbic acid did not increase iron absorption.

The absorption of the 2 different doses of zinc (5 and 10 mg) provided as Sprinkles was somewhat lower than expected. Geometric mean percentage zinc absorption was 6.4% (min-max: 1.7–14.6%) for the 5-mg dose and 7.5% (min-max: 3.3–18.0%) for the 10-mg dose. There were no significant differences in the percentage of absorption between the 2 zinc doses although the total amount of zinc absorbed in the 10-mg dose was significantly greater. Others reported similar low zinc absorption values from fortified foods that included both iron and zinc (17,18). However, it is difficult to compare our results with those of others who used different forms and doses of iron and zinc, different vehicles for fortification, and different study populations.

Based on studies that demonstrated no effect on zinc absorption from iron-fortified weaning cereals or infant formula,

**TABLE 1**

Baseline characteristics and hematological indices of young children provided with $[^{57}$Fe] ferrous fumarate and/or $[^{67}$Zn] zinc gluconate as Sprinkles

<table>
<thead>
<tr>
<th>Group</th>
<th>LoZn</th>
<th>HiZn</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>21</td>
<td>21</td>
<td>18</td>
</tr>
<tr>
<td>Infant characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, mo</td>
<td>17.2 ± 4.1</td>
<td>16.8 ± 3.0</td>
<td>15.4 ± 6.0</td>
</tr>
<tr>
<td>Male gender</td>
<td>12 (57)</td>
<td>9 (43)</td>
<td>7 (39)</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>77.0 ± 5.1</td>
<td>75.7 ± 4.2</td>
<td>76.5 ± 4.7</td>
</tr>
<tr>
<td>Hematological indices</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plasma Zn, μmol/L</td>
<td>21.5 ± 11.0</td>
<td>21.2 ± 9.4</td>
<td>17.6 ± 6.7</td>
</tr>
<tr>
<td>Hemoglobin, g/L</td>
<td>94.6 ± 8.6</td>
<td>102.9 ± 12.2</td>
<td>99.6 ± 15.7</td>
</tr>
<tr>
<td>stTfR &gt; 8.5 mg/L</td>
<td>16 (80)</td>
<td>15 (71)</td>
<td>13 (72)</td>
</tr>
</tbody>
</table>

Values are means ± SD or n (%).

**Effect of zinc and ascorbic acid on iron absorption**

Information on the validation of the $^{57}$Fe-labeled i.v. infusion administered to the control group and on the calculation of iron absorption was reported elsewhere (3). The percentage and total amount of erythrocyte incorporation of iron or iron absorbed between the LoZn and HiZn groups and between the LoZn and control groups did not differ (Table 2).

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Based on studies that demonstrated no effect on zinc absorption from iron-fortified weaning cereals or infant formula,

**TABLE 2**

Erythrocyte incorporation of Fe and Fe absorption in young children from $[^{67}$Fe] ferrous fumarate and Zn absorption from $[^{67}$Zn] zinc gluconate ingested as Sprinkles

<table>
<thead>
<tr>
<th>Group</th>
<th>LoZn</th>
<th>HiZn</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>% of dose</td>
<td>6.4 (1.7–14.6)</td>
<td>7.5 (3.3–18.0)</td>
</tr>
<tr>
<td>Total Zn, mg</td>
<td>0.31 (0.08–0.73)</td>
<td>0.82 (0.33–1.82)</td>
</tr>
<tr>
<td>n</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>% of dose</td>
<td>4.46 (0.57–15.8)</td>
<td>3.28 (0.48–9.2)</td>
</tr>
<tr>
<td>Total Fe, mg</td>
<td>1.34 (0.17–4.7)</td>
<td>0.98 (0.14–2.8)</td>
</tr>
<tr>
<td>n</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>% of dose</td>
<td>5.94 (0.77–21.0)</td>
<td>4.37 (0.64–12.3)</td>
</tr>
<tr>
<td>Total Fe, mg</td>
<td>1.78 (0.23–6.3)</td>
<td>1.31 (0.19–3.7)</td>
</tr>
</tbody>
</table>

Values are geometric means (min–max). Means in a row with different superscript letters differ, $P < 0.05$

$^2$Calculated on the assumption that the percentage incorporation of total Fe was identical to the percentage incorporation of the $^{57}$Fe label.
or from iron supplements taken with food, we expected better zinc absorption than we observed (19–22). Indeed, in 4 studies in adults or young children, zinc absorption from fortified iron food was between 25 and 40% (19,20,23,24). In addition, recent estimates of zinc absorption from typical diets found in several developing countries including Ghana were reported to be 30% (25); however, these foods had no added iron. Similar to the inhibiting effect on iron, phytate was shown to bind zinc and form insoluble complexes, thereby reducing its absorption (26). However, given the relatively high absorption of zinc from foods typically eaten in Ghana, a high phytate content is not likely to be responsible for the low zinc absorption observed in the current study (25). It is more likely that the lower than expected zinc absorption values found in the current study were a result of the relatively high iron dose (30 mg), which was concomitantly added to the complementary food.

The effect of iron on zinc absorption could not be investigated in the current study because only 1 iron dose was administered. However, the high Fe:Zn molar ratios (7:1 in Sprinkles containing 5 mg zinc and 3.5:1 in Sprinkles containing 10 mg zinc) may have inhibited zinc absorption through competition for a common absorptive pathway on luminal intestinal mucosal cells. Indeed, it was demonstrated that when both iron and zinc are provided at a Fe:Zn molar ratio exceeding 2:1, the fractional absorption of zinc is substantially reduced (27). It is possible that there is absorptive competition between iron and zinc on the divalent metal transporter-1 (DMT1) (28). However, a recent review suggested that zinc may not be transported by DMT1, and thus it is unlikely that the DMT1 is a site of inhibition (29). The possible mechanisms of zinc uptake remain to be determined (30).

Because the absorption efficiency (in terms of percentage) did not differ between the 2 zinc doses, the higher dose resulted in significantly more zinc being absorbed. Geometric mean total zinc absorbed was 0.31 mg for the 5-mg zinc dose and 0.82 mg for the 10-mg zinc dose. Comparing these absorbed values with the requirement for absorbed zinc for children aged 1–3 y (0.74 mg/d for absorbed zinc), only the higher dose of zinc would be expected to meet the requirements for absorbed zinc (11). The lower dose would contribute ~42% of the absorbed zinc requirement for children in this age group.

Similar to iron, there are several approaches for estimating zinc absorption from foods or supplements. However, unlike iron, studies on zinc absorption in young children using stable isotopes are limited because zinc stable isotopes techniques are still relatively novel (26). To date, studies investigating zinc absorption in young children have involved collecting urine and/or fecal samples when giving oral and i.v. isotopic zinc doses (17,26,30–34). In the present study, it was not feasible to collect urine samples with any accuracy. Therefore, we chose to take plasma samples instead (35). One study in pregnant women used a method similar to that described here (14).

The values for iron absorption reported here do not differ considerably from those found in our previous study on iron absorption from Sprinkles, done in a similar sample of young children but without added zinc. These results support recent evidence suggesting that zinc does not inhibit iron absorption (29). However, a number of field trials of zinc and iron supplementation suggested the opposite (8–10,23). These trials demonstrated that the hemoglobin response to supplementary iron is adversely affected by the concomitant addition of zinc to the supplement. For example, a recent study using Sprinkles as the vehicle to deliver micronutrients demonstrated a compromise in the reduction in anemia prevalence with zinc + iron compared with iron Sprinkles alone (10). Kordas and Stoltzfus (29) speculated that the interaction between iron and zinc that occurred in such supplementation trials may be postabsorptive.

Although we did not demonstrate an effect of ascorbic acid on iron absorption in the current study, the promoting effect of ascorbic acid and its ability to counteract the negative effects of phytic acid on iron absorption have been well described (36). However, there is limited and contradictory evidence using ferrous fumarate as the iron source, and no studies have evaluated the effect of ascorbic acid on iron absorption from microencapsulated ferrous fumarate added to maize-based complementary foods. Only 1 of 3 studies showed an increase in iron absorption from ferrous fumarate with added ascorbic acid at an ascorbic acid-iron molar ratio higher (4:1) than that used in the current study (0.5:1) (6,7,37). The effect of ascorbic acid on iron absorption should be further investigated.

Limited statistical power is the most common reason for not finding a significant difference. This could have been one reason for the lack of effect of ascorbic acid and zinc intake on iron absorption. However, in a previous iron absorption study conducted with Sprinkles, it was calculated that 17 children/group would have 80% power to reject the hypothesis that the mean difference in iron absorption between the 2 groups was zero (3). Thus, the current study appears to have adequate power.

Although the results of this study can be generalized to countries in which maize-based complementary foods are the norm, we do not know whether the absorption characteristics of iron and zinc from Sprinkles would be similar in rice- or wheat-based complementary foods with similar or lower amounts of phytic acid. Despite the relatively low absorption of zinc, Sprinkles with either 5 or 10 mg zinc would contribute substantially to the absorbed zinc requirements for infants and young children and would not compromise iron absorption. Future research should explore the effect of other types of complementary foods on iron and zinc absorption from Sprinkles.

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**LITERATURE CITED**


