

Soluble and Insoluble Fe, Zn, Ca, and Phytates in Foods Commonly Consumed in Northern Mexico

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In northern Mexico, refried beans and corn and flour tortillas are basic foods. Cereals and legumes are high in phytates and affect mineral absorption. The objective of this study was to determine total phytate and Fe, Zn, and Ca content in these foods and their solubility. Refried beans contained 622 ± 95 mg of phytates/100 g, corn tortillas, 448 ± 40 mg/100 g, and flour tortillas, 123 ± 18 mg/100 g. On the basis of the daily intake of these foods, refried beans provide 861 mg/day of phytates, corn tortillas, 650 mg/day, and flour tortillas, 97 mg/day, for a total of 1608 mg/day. The majority of the phytates are in the insoluble fraction. Refried beans contained 6.05 ± 1.19 mg of Fe/100 g, 3.03 ± 0.12 mg of Zn/100 g, and 170.9 ± 33.3 mg of Ca/100 g. Corn tortillas contained 4.06 ± 1.04 mg of Fe/100 g, 2.55 ± 0.42 mg of Zn/100 g, and 167.9 ± 41.7 mg of Ca/100 g. Flour tortillas had 2.08 ± 0.02 mg of Fe/100 g, 1.40 ± 0.50 mg of Zn/100 g, and 38.9 ± 12.4 mg of Ca/100 g. The majority of the Fe and Zn is in the insoluble fractions. A larger percentage of the Ca was found in the soluble fraction. Due to the insolubility of these minerals and high phytate content, absorption of minerals is probably reduced.

Keywords: Fe, Zn, Ca solubility; phytate solubility; mineral composition

INTRODUCTION

Phytic acid (*myo*-inositol hexaphosphoric acid) is the principal phosphorus compound in cereals and legumes. One of the problems with this compound in foods is its great potential to bind minerals, forming insoluble mineral-phytate complexes, making them unavailable for man and animals (Cheryan, 1980).

In developing countries, diets are high in cereals and legumes and therefore high in fiber and phytates. Harland (1989) showed mineral deficiencies in these diets were attributed to the presence of phytates that interfered with mineral absorption. Iron and zinc deficiencies have been demonstrated with diets high in phytates (Forbes et al., 1984; Hallberg et al., 1989; Nolan et al., 1987). Wise (1983) showed Ca plays an important role in the formation of other phytate mineral complexes.

Our center over the past decade has studied the diet patterns in northern Mexico and has characterized the Sonoran diet. Ballesteros et al. (1993) reported beans and corn and flour tortillas are basic foods with an average daily consumption of 218, 184, and 153 g, respectively. These foods are also the major contributors of fiber in the Sonoran diet, which is considered relatively high. Since the phytates are associated with dietary fiber (Wise, 1983; Harland, 1989), the objectives of this study were to quantify the phytate content in the foods of major consumption, to determine Fe, Zn, and Ca levels in these foods, and to determine the solubility of the phytates and the minerals.

MATERIALS AND METHODS

Samples of pinto beans (*Phaseolus vulgaris*) and corn tortillas were purchased from four different commercial locations in the city of Hermosillo, Mexico. Four different brands

of flour tortillas were purchased. The pinto beans were cooked and prepared as refried beans according to traditional recipes (Camou et al., 1990). The corn tortillas consisted of the following formulations: maseca (from two different locations, which is ground corn including parts of the cob), lime-treated ground corn kernels only, and a mixture of the maseca and ground corn.

The samples were ground in a Waring Blendor (Waring Products Corp. of America, New Hartford, CT), passed through a 100 mesh, and then dried in a forced-air convection oven at 56 °C overnight (Blue M C4850Q, Blue Island, IL). The moisture content of the samples, as purchased or in the case of the refried beans as prepared, were determined according to AOAC (1990, Section 220.1) methods. The samples were then stored in desiccators for further analysis.

Phytate Determinations. The AOAC method (1990, Section 986.11) was used to determine total phytate in the samples. The method was modified slightly in the digestion procedure. If digestion was incomplete after treatment with acids as specified in the technique, the samples were placed in a muffle furnace for 8 h at 535 °C. The method was validated with a reference material, Red Wheat Bran (American Association of Cereal Chemists, 3340 Pilot Knob Road, St. Paul, MN 55121) using the values for phytates reported by Harland and Oberleas (1986) and Harland et al. (1988).

Mineral Analysis. The minerals Fe, Zn, and Ca were determined in the foods and the soluble and insoluble fractions by the AOAC method (1990, Section 968.08). The samples were predigested by adding 3 mL of a mixture of acids (sulfuric-nitric 1:4; Merck, Mexico) to 1 g of sample and then placed in a muffle furnace for 8 h at 535 °C. The samples were made to volume with deionized water containing 1% HCL (Merck). If digestion was incomplete in the muffle furnace, a wet acid digestion was used (Noller and Bloom, 1978). The minerals were determined by atomic absorption using a Varian Spectr AA-20 (Varian Techntron Pty Ltd., Mulgrave, VIC, Australia). The technique was validated using a NBS standard, bovine liver 1577b (NIST, Gaithersburg, MD).

Determination of Soluble and Insoluble Fractions. The method of Rao and Prabhavathi (1978) was used to digest the samples with pepsin (Sigma Chemical Co., St. Louis, MO). After centrifuging (45 min, 3000 rpm) (IEC Centra-4B Centrifuge, International Equipment Co., Needham Heights MA), the phytate and minerals were determined directly in the

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Table 1. Content of Phytates in Refried Beans and Corn and Flour Tortillas

food	location	total phytates, ^a mg/100 g of dry wt
refried beans	1	502 ± 57 ^a
	2	621 ± 88 ^{ab}
	3	632 ± 52 ^{ab}
	4	734 ± 62 ^b
	mean ± SD	622 ± 95
corn tortillas	corn	486 ± 42 ^a
	maseca ^b	407 ± 5 ^b
	corn and maseca	479 ± 19 ^a
	maseca	421 ± 18
	mean ± SD	488 ± 40
flour tortillas	1	101 ± 7 ^c
	2	117 ± 10 ^{bc}
	3	135 ± 9 ^{ab}
	4	142 ± 4 ^a
	mean ± SD	123 ± 18

^a Mean ± SD, triplicate analysis. Values with different superscripts are significantly different ($p < 0.05$). ^b Different location.

supernatant after being filtered with Whatman No. 44 filter paper. A reagent blank was used in all determinations. The insoluble fraction was digested according to the AOAC method (1990, Section 968.08).

Statistical Analysis. An analysis of variance of means from the different locations was conducted, and the means were compared by the Tukey multiple-range test (SAS, 1989).

RESULTS AND DISCUSSION

Table 1 represents the total phytates in refried beans and corn and flour tortillas. The values for refried beans ranged from 502 to 734 mg/100 g with a mean value of 622 ± 95 mg/100 g of dry wt. There was a significant difference ($p < 0.05$) between the beans purchased from sources 1 and 4. This difference could easily be due to the variation that exists in plants of the same variety (Graf and Dintzis, 1982). Lolas et al. (1976) reported a range of 540–1580 mg of phytates/100 g of dry wt in raw pinto beans using a colorimetric method. Graf and Dintzis (1982) obtained values of 1400 ± 30 mg/100 g in raw dehydrated pinto beans. Harland et al. (1988), using the same technique of this study, reported 685 ± 5 mg/100 g of dry wt in pinto beans. Utilizing the average consumption figure of 329 g (Wyatt et al., 1994), which is representative of the average refried bean consumption for adults from the low socioeconomic level in northern Mexico, gave an average daily phytate consumption from beans of 861 mg. Hallberg et al. (1989) showed a reduction in Fe bioavailability with a daily intake of 250 mg or more of phytates.

Corn tortillas had a range of phytates from 407 to 486 mg/100 g with an average value of 448 ± 40 mg/100 g of dry wt. Significant differences ($p < 0.05$) were found between the two samples made from maseca, but no differences were found between the samples that contained lime-treated ground corn. A great variation exists in the preparation and formulas of commercial corn tortillas by different establishments. No values for phytates in commercial corn tortillas were found in the literature; however, Franz et al. (1980) reported 828 ± 106, 776 ± 39, 872 ± 11 mg of phytates/100 g of dry wt in raw corn, cooked corn, and cooked lye-treated corn, respectively. On the basis of a daily consumption of 253 g (Wyatt et al., 1994) of corn tortillas for adults 25 years

Table 2. Mineral (Fe, Zn, Ca) Content of Foods of Major Consumption in Sonora, Mexico

food	location	mg/100 g of dry wt ^a		
		Fe	Zn	Ca
refried beans	1	5.11 ± 0.11 ^c	3.01 ± 0.01 ^{ab}	194.8 ± 3.3 ^a
	2	5.03 ± 0.05 ^c	3.06 ± 0.02 ^{ab}	200.3 ± 4.2 ^a
	3	7.50 ± 0.19 ^a	3.17 ± 0.21 ^a	159.5 ± 3.5 ^b
	4	6.55 ± 0.20 ^b	2.87 ± 0.20 ^c	128.9 ± 4.5 ^c
	mean ± SD	6.05 ± 1.19	3.03 ± 0.12	170.9 ± 33.31
corn tortillas	1	5.50 ± 0.50 ^a	2.59 ± 0.50 ^a	183.5 ± 1.0 ^b
	2	4.04 ± 0.10 ^b	2.06 ± 0.10 ^a	180.0 ± 2.0 ^b
	3	3.09 ± 0.50 ^c	3.08 ± 0.50 ^a	201.1 ± 5.0 ^a
	4	3.59 ± 0.16 ^b	2.47 ± 0.10 ^a	106.9 ± 1.2 ^c
	mean ± SD	4.06 ± 1.04	2.55 ± 0.42	167.9 ± 41.7
flour tortillas	1	2.09 ± 0.02 ^b	2.06 ± 0.07 ^a	52.3 ± 3.0 ^a
	2	2.08 ± 0.01 ^b	1.50 ± 0.02 ^{ab}	43.6 ± 5.0 ^b
	3	2.06 ± 0.02 ^b	1.10 ± 0.10 ^b	36.6 ± 4.5 ^c
	4 ^b	5.84 ± 0.19 ^a	0.93 ± 0.01 ^b	22.9 ± 1.1 ^d
	mean ± SD	2.08 ± 0.02	1.40 ± 0.50	38.9 ± 12.4

^a Mean ± SD in triplicate. Values with different superscripts are significantly different (Turkey, $p < 0.05$). ^b Iron enriched (brand not included in mean).

or older, corn tortillas provide an ingestion of 650 mg of phytates.

Phytates in flour tortillas ranged from 101 to 142 mg/100 g of dry wt with an average of 123 ± 18 mg/100 g. There were significant differences among the different commercial brands, probably indicating the variations in the wheat flour used and the difference in formulations. Proportions of ingredients vary greatly in products in Mexico. Graf and Dintzis (1982) reported 230 mg of phytates/100 g of dry wt in enriched wheat flour. Franz et al. (1980) reported refined wheat flour contained 40 mg/100 g of dry wt, and Oberleas and Harland (1981) reported 281.6 mg/100 g in the edible portion of wheat flour. Values for phytates in commercial flour tortillas could not be found. A daily ingestion of 105 g of flour tortillas (Wyatt et al., 1994), gives a daily ingestion of 97 mg of phytates. Due to the fact that these three foods, refried beans and corn and flour tortillas, represent the major foods consumed daily by the majority of the population in northern Mexico, the content of phytates in the diet is substantially high and interference with mineral absorption is a real possibility.

Mineral Content in Refried Beans and Corn and Flour Tortillas. Table 2 presents the content of Fe, Zn, and Ca in refried beans and corn and flour tortillas.

Fe in Refried Beans. Fe content in refried beans ranged from 5.03 to 7.59 mg/100 g of dry wt with an average of 6.05 ± 1.19 mg/100 g. Significant differences were found among some of the beans purchased from different sources. Similar differences were reported by Nabhan et al. (1985) in seven different samples of pinto beans collected at different places, which showed a range of 2.8–8.1 mg of Fe/100 g of dry wt. Koehler et al. (1987) reported values of 4.47–8.27 mg of Fe/100 g of dry wt in 13 different cultivars of pinto beans. The mean Fe content in this study compares very well with values reported by other authors for refried beans, 4.9 (Grijalva et al., 1994), 5.12 (García-López and Wyatt, 1982), and 5.2 mg/100 g of edible portion (Hernández et al., 1987). On the basis of a daily consumption of 329 g of refried beans for adults of low socioeconomic level (Wyatt et al., 1994), the Fe intake from beans is

7.33 mg or 73.3% of the RDA for men and 48.9% for women (NAS, 1989). Many studies have reported that beans are a good source of Fe in the diets of developing countries; however, one must remember that Fe from legumes is of low bioavailability (Gillooly et al., 1983), and due to the high intake of phytates in the northern Mexico diets, there may be some interferences with absorption.

Zn in Refried Beans. Several studies have shown that phytates in cereals and legumes form insoluble compounds with Zn and Ca (Erdman, 1981; Franz et al., 1980; Davies et al., 1985; Maga, 1982). Zn in refried beans ranged from 2.87 to 3.17 mg/100 g of dry wt, with a mean of 3.03 ± 0.12 mg/100 g. Some differences were noted among the different sources ($p < 0.05$). Grijalva et al. (1994) reported 1.0 mg/100 g of dry wt in refried beans, while Koehler et al. (1987) reported values of 2.4–3.0 mg/100 g of dry wt for 13 samples of raw pinto beans from different cultivars and Nabhan et al. (1985) showed values of 2.7–4.4 mg/100 g of dry wt in 7 samples of raw pinto beans from different sources. With a consumption of refried beans as reported by Wyatt et al. (1994), beans provide 3.52 mg of Zn daily, which represents 23.55% of the RDA (NAS, 1989).

Ca in Refried Beans. The range of Ca in refried beans was from 128.9 to 200.3 mg/100 g, average of 170.9 ± 33.3 mg/100 g of dry wt, and significant differences were noted among the different sources. Grijalva et al. (1994) reported values of 150 mg of Ca/100 g of dry wt in refried beans. Nabhan et al. (1985) reported 126.8–329.5 mg/100 g of dry wt in seven samples of raw beans collected in different places. Koehler et al. (1987) reported 127–173 mg of Ca/100 g of dry wt in raw pinto beans of different cultivars. On the basis of the consumption of refried beans (Wyatt et al., 1994), refried beans could provide 1105 mg of Ca/day or 138% of the RDA.

Fe in Corn Tortillas. Fe in corn tortillas ranged from 3.09 to 5.50 mg/100 g of dry wt with an average of 4.06 ± 1.04 mg/100 g, and significant differences were noted in tortillas of different preparations. Grijalva et al. (1994) reported 6.3 mg of Fe/100 g of dry wt, and García-López and Wyatt (1982) reported 2.66 mg/100 g of dry wt. Hernández et al. (1987) reported 2.5 mg/100 g in the edible portion. Considering the consumption of corn tortillas in adults 25 years or older is 253 g/day (Wyatt et al., 1994), this represents a consumption of 4.93 mg of Fe in the diet or 49.3% of the RDA for men and 32.9% for women (NAS, 1989).

Zn in Corn Tortillas. Corn tortillas had 2.06–3.08 mg of Zn/100 g, an average of 2.55 ± 0.42 mg/100 g of dry wt, and no significant differences were noted in the different preparations. Grijalva et al. (1994) reported 1.5 mg/100 g of dry wt, which is lower than the values reported in this study. On the basis of the consumption of corn tortillas (Wyatt et al., 1994), they provide 2.98 mg of Zn daily equivalent or 19.98% of the RDA.

Ca in Corn Tortillas. Treating corn with lime for making tortillas imparts considerable Ca, and corn tortillas have been considered an important source of Ca in the Mexican diet. Corn tortillas in this study contained 106.9–201.1 mg/100 g of dry wt, an average of 167.9 ± 41.7 mg/100 g of dry wt, with significant differences between the formulations. The difference probably reflects the lack of quality control in the lye treatment of the corn and variations in the quantity of lye-treated corn flour used in the formulations. Grijalva et al. (1994) reported a content of 175 mg/100 g of dry wt, and Hernández et al. (1987) obtained a value of 108

Table 3. Soluble and Insoluble Phytates in Refried Beans and Corn and Flour Tortillas

food	mg/100 g of dry wt ^a			% insoluble
	soluble	insoluble	total	
refried beans	170 ± 9	529 ± 51	602 ± 7	87.87
corn tortillas	119 ± 9	279 ± 48	410 ± 44	68.04
flour tortillas	68 ± 27	99 ± 17	143 ± 6	69.20

^a Mean ± SD, triplicate analysis.

mg of Ca/100 g in the edible portion. Corn tortillas are an important part of the Mexican diet (Wyatt et al., 1994), providing 214.2 mg of Ca daily for adults 25 years or older of low socioeconomic level or 26.8% of the RDA (NAS, 1989).

Fe in Flour Tortillas. For regular commercial flour tortillas an average of 2.08 ± 0.02 Fe/100 g of dry wt is reported in Table 2. Sample 4 was enriched with Fe, thus having a value of 5.84 mg/100 g of dry wt. No significant differences were detected in the three regular commercial brands. Grijalva et al. (1994) reported 7 mg/100 g of dry wt in flour tortillas. This value is much higher than the value encountered in this study. Hermann et al. (1979) reported 1.4–3.2 mg/100 g of wet wt in three different types of flour tortillas. Flour tortillas are also an important food in the diet of Sonora, with a consumption of 105 g (Wyatt et al., 1994); this represents 1.53 mg of Fe/day from flour tortillas or 15.3% of the RDA for men and 10.2% for women. Taking into consideration the consumption of all three foods, they could potentially provide 137.9% of the RDA for Fe for men and 92.0% for women.

Zn in Flour Tortillas. Zn in flour tortillas ranged from 0.93 to 2.096 mg/100 g of dry wt, an average of 1.40 ± 0.50 mg/100 g. Significant differences were found between the different commercial brands. Grijalva et al. (1994) reported 1.4 mg/100 g of dry wt in commercial flour tortillas, corresponding very well with the results of this study. Flour tortillas provide 1.13 mg/day of Zn in the diet of adults in Sonora (Wyatt et al., 1994) or 7.5% of the RDA. Taking into consideration all three of the major foods, they provide 50.9% of the Zn RDA.

Ca in Flour Tortillas. Ca ranged from 22.9 to 52.3 mg/100 g of dry wt, with an average of 38.9 ± 12.4 mg/100 g of dry wt, with significant differences in the commercial brands, indicating a lack of standardization in the preparation of this product. Grijalva et al. (1994) reported 63 mg/100 g in a brand similar to those of this study. The flour tortilla provides 34.6 mg of Ca/day in the diet of Sonora, which is 4.3% of the Ca RDA. Taking into consideration the consumption of all three of the major foods, they provide 169.1% of the Ca RDA.

Soluble and Insoluble Phytates in Refried Beans and Corn and Flour Tortillas. Table 3 presents the soluble and insoluble phytates in refried beans and corn and flour tortillas. The majority (87.87%) of the phytates was found to exist in the insoluble fraction in refried beans, 529 mg/100 g, compared to 170 mg/100 g of dry wt in the soluble fraction. For refried beans no studies on the solubility of phytates were found in the literature; however, it is well accepted that phytates are associated with dietary fiber (Wise, 1983; Harland, 1989). Hughes and Swanson (1989) showed in white and black beans (*P. vulgaris*) 7% soluble dietary fiber and 13% insoluble dietary fiber.

Corn tortillas contained 279 mg/100 g insoluble phytates and 119 mg/100 g soluble phytates, which represents 68.04% of the total phytates as insoluble.

Table 4. Content of Minerals in the Soluble and Insoluble Fraction in Foods of Major Consumption

food	mg/100 g of dry wt ^a			%
	soluble	insoluble	total	
Fe				
refried beans	0.74 ± 0.21	5.26 ± 0.5	6.89 ± 0.47	87.66
corn tortillas	1.08 ± 0.16	2.69 ± 0.19	3.65 ± 0.12	73.69
flour tortillas	0.31 ± 0.01	1.25 ± 0.04	1.75 ± 0.21	71.42
Zn				
refried beans	0.86 ± 0.05	2.28 ± 0.51	2.98 ± 0.04	76.51
corn tortillas	0.89 ± 0.04	2.07 ± 0.01	2.23 ± 0.02	69.93
flour tortillas	0.10 ± 0.06	1.04 ± 0.01	1.41 ± 0.01	70.92
Ca				
refried beans	114 ± 4	59 ± 1	186 ± 6	61.29
corn tortillas	106 ± 1	56 ± 6	158 ± 1	67.08
flour tortillas	36 ± 4	6 ± 1	43 ± 2	83.72

^a Mean ± SD, triplicate analysis.

Flour tortillas contained 99 mg/100 g insoluble phytates and 68 mg/100 g soluble phytates; that is, 69.2% of the total phytates existed in the insoluble fraction. In comparison to the other foods, flour tortillas have a slightly higher percentage of soluble phytates. It is possible that during the preparation of the tortillas some enzymatic action occurs, thus producing more soluble phytates (Nayini and Makakis, 1986).

Soluble and Insoluble Minerals in Foods of Major Consumption. Many studies have shown that absorption of minerals in the intestines is related to their solubility and that foods of vegetable origin such as beans, corn, and wheat can interfere with the solubility of minerals (Champagne et al., 1985; Nolan et al., 1987; Platt and Clydesdale, 1987). Table 4 presents the soluble and insoluble minerals in refried beans and corn and flour tortillas.

Iron. Iron is found in the insoluble fraction in refried beans and corn and flour tortillas (Table 4). In refried beans 5.26 mg/100 g of dry wt, or 87.66% of the total Fe, in corn tortillas 2.60 mg/100 g of dry wt, or 73.69% of the total Fe, and in flour tortillas 1.25 mg/100 g of dry wt, or 71.42% of the total Fe existed in the insoluble fractions. Many factors influence the binding of minerals by phytates such as pH, concentration and presence of other minerals such as Ca and Zn. García-López and Wyatt (1982) reported 39% solubility of iron in cooked beans and 79% in corn tortillas. These values are much higher than those reported in this study.

Zinc. As with iron, the majority of the mineral Zn exists in the insoluble fraction. In refried beans 2.28 mg/100 g, or 76.51% of the total Zn, in corn tortillas, 2.07 mg/100 g, or 69.93% of the total Zn and in flour tortillas 1.04 mg/100 g, or 70.92% of the total Zn, were in the insoluble fraction (Table 4). No data exist in the literature for comparison.

Calcium. Ca exists in the soluble and insoluble fractions in foods of major consumption (Table 4). A different relationship was observed with regard to the solubility of Ca in the foods of major consumption. The majority of Ca in refried beans is in the soluble fraction, 114 mg/100 g or 61.29%; in corn tortillas 106 mg/100 g, or 67.08% of the total calcium, and in flour tortillas 36 mg/100 g, or 83.72% of the total Ca, were in the soluble fractions. We were not able to find any comparative studies in the literature on solubility of minerals in these foods; however, Rao and Rao (1984) showed that 69% of the total Ca, dry wt, was soluble in cooked rice.

Molar Ratios of Phytates and Minerals in Foods of Major Consumption. Several authors have indicated that different molar ratios are good indicators of

Table 5. Molar Ratios of Phytates and Minerals in Foods of Major Consumption in Sonora, Mexico

food	location	Phy/Zn ^a	Ca/Phy ^b	[Ca]/[Phy]/[Zn] ^c
refried beans				
(<i>P. vulgaris</i> var. Pinto)	1	16.5	6.4	1.07
	2	20.0	5.3	1.00
	3	19.7	4.2	0.78
	4	25.3	2.9	0.82
	mean	20.4 ± 3.6	4.7 ± 1.5	0.92 ± 1.4
corn tortillas				
corn		18.5	6.2	0.85
maseca ^d		19.6	7.3	0.88
corn and maseca		15.4	6.9	0.77
maseca		16.8	4.2	0.45
	mean	17.6 ± 1.9	6.2 ± 1.4	0.74 ± 0.20
flour tortilla				
commercial brand				
	1	4.8	8.5	0.06
	2	7.7	6.1	0.08
	3	12.1	4.5	0.11
	4	15.1	2.7	0.08
	mean	9.9 ± 4.6	5.5 ± 2.5	0.08 ± 0.02

^a (mg of PHY/MW (molecular weight) of PHY:mg of Zn/MW of Zn). ^b (mg of Ca/MW of Ca:mg of PHY/MW of PHY). ^c (mol/kg Ca)/(mol/kg PHY)/(mol/kg Zn). ^d Different location.

bioavailability of Zn (Oberleas and Harland, 1981; Morris and Ellis, 1981). Oberleas and Harland (1981) showed that foods with a molar ratio of Phy:Zn less than 10 showed adequate availability of Zn and problems were encountered if the value was greater than 15. In Table 5 the Phy:Zn ratios are shown for the foods of major consumption. All samples of refried beans had values greater than 15, with an average of 20.4, which could indicate low Zn availability. Corn tortillas also had values greater than 15, with an average of 17.6. In the case of flour tortillas the values were lower, with an average of 9.9, indicating that Zn is probably more available in flour tortillas. Franz et al. (1980) determined molar ratios in corn, cooked and raw, finding ratios of 30 and 33. They also found values much higher than those reported in this study for lima and white beans. These same authors demonstrated a lower availability of Zn in rats when fed foods with high molar ratios of Phy:Zn. Forbes et al. (1984) showed an inverse relationship between the micrograms of Zn in the tibia of rats and the molar ratio Phy:Zn.

Wise (1983) suggested the solubility of the phytates and the proportion of Zn bound in a mineral complex in the intestines depend on the levels of Ca and that at molar ratios of Ca:Phy less than 6 the precipitation of Zn is incomplete and a portion remains in solution and thus available. In Table 5 one can see that the individual values for the three foods studied varied considerably. For beans the average was 4.7, for corn tortillas the values were higher but with an average very close to 6 (6.2), and the values had a wider range for flour tortillas but an average of 5.5 ± 2.5 was calculated. Ferguson et al. (1988, 1989) showed that the molar ratio varies with different foods and recommended that this value be used in conjunction with other data to explain the availability of Zn using the Ca:Phy ratio.

Also in Table 5 are presented the values for the molar ratios of [Ca]/[Phy]/[Zn]. Ellis et al. (1987) indicated the ratio of [Ca]/[Phy]/[Zn] is a better predictor of Zn availability and said that if the value is greater than

0.5 there could be interferences with the availability of Zn. In Table 5 it can be shown that refried beans and corn tortillas had values greater than 0.5 with averages of 0.92 and 0.74, respectively. Only for flour tortillas was the value below 0.5, with an average of 0.08 ± 0.02 . That is to say, using this indicator, Zn availability would be affected in refried beans and corn tortillas.

Conclusions. The basic foods in the Sonoran diet, refried beans and corn and flour tortillas, were found to be high in insoluble phytates, contributing an intake of 1608 mg of phytates daily. It is likely that high phytate intake interferes with mineral absorption. The majority of the Fe and Zn are in the insoluble fraction, also indicating a potential problem with absorption; however, Ca is more soluble and thus probably more available. Even though these foods provide a substantial quantity of Fe, Zn, and Ca in the daily intake of these three foods, it is felt a large portion of these minerals may not be available due to their insolubility; however, further in vivo studies are needed to determine the exact availability of minerals in these major foods.

On the basis of the evaluation of the foods using certain molar ratios of phytates to Zn and Ca that indicate the bioavailability of these minerals, refried beans and corn tortillas may have reduced mineral availability.

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