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Preparation effects on tortilla mineral content in Guatemala

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SUMMARY. We have previously reported that in Guatemala, the calcium, iron, and zinc contents of tortillas from rural areas are higher than that of tortillas from urban centers.. This study examines variation in the calcium, iron, zinc and copper content of tortilla according to the implements used for making tortillas and inquires as to whether preparation effects mediate rural-urban variation in tortilla mineral content. Tortilla samples and information on how the tortillas were prepared were collected from the female heads of a total of 50 households from three rural, two semi-urban and one low income urban community. Samples of lime used for making tortillas were collected from 31 households. To grind masa, a hand mill was found to be used in some rural households whereas a motorized mill predominated in the semi-urban and urban areas. Most women used grinding stones called the «mano y metate» to further refine the texture of the masa. Tortillas prepared with the combined use of the hand mill and «mano y metate» had a significantly ($p<0.05$) higher iron content. Use of the «mano y metate» was also associated with a significantly ($p<0.05$) higher zinc content. These results suggest that the use of certain grinding implements may mediate rural-urban variation in tortilla iron and zinc content. The cooking surface, pot used for nixtamalization, source of water, and amount of lime used did not significantly account for variation in the content of these minerals. Key words: Tortilla, preparation effects, iron , zinc, Guatemala

RESUMEN. Efectos de la preparación sobre el contenido de minerales en la tortilla. Guatemala. Previamente hemos comunicado que el contenido de calcio, hierro y zinc es más alto en tortillas de maíz provenientes de áreas rurales que en aquellas de áreas urbanas de Guatemala. Este estudio investigó la variación en el contenido de calcio, hierro, zinc y cobre de tortillas de acuedo a los implementos utilizados para su preparación; interesó conocer además, si estos efectos explican las diferencias urbano-rural en cuanto a la composición de minerales reportadas anteriormente. Se estudió un total de 50 hogares ubicados en: tres comunidades rurales, dos semi-urbanas y una localidad urbana de bajo nivel socioeconómico. Se entrevistó a las dueñas de casa requiriendo información respecto a la forma de preparación de las tortillas, colectándose simultáneamente muestras de esas. En 31 hogares se tomaron además, muestras de la cal utilizada para la cocción del maíz. Como instrumento de molienda del maíz cocido (masa), se encontró el uso de molinos manuales en algunas áreas rurales, en cambio el molino motorizado es la opción más utilizada en áreas urbanas y semi-urbanas. La mayoría de las mujeres utiliza mano y metate para refinar la textura de la masa. Tortillas preparadas utilizando en forma combinada el molino manual y mano, y metate presentaron un contenido significativamente mayor del hiero; el empleo de mano y metate también ocasionó un incremento en el contenido de zinc. Estos resultados sugieren que los implementos usados en la molienda del maíz pueden mediar las variaciones rural-urbano del contenido de hierro y zinc en tortillas. Otros factores como la superficie de cocción, tipo de olla usada en el proceso de nixtamalización, origen del agua y cantidad de cal, no mostraron efectos significativos sobre el contenido mineral de las tortillas. Palabras claves: Tortilla, efectos de preparación, hierro, zinc, Guatemala.

INTRODUCTION

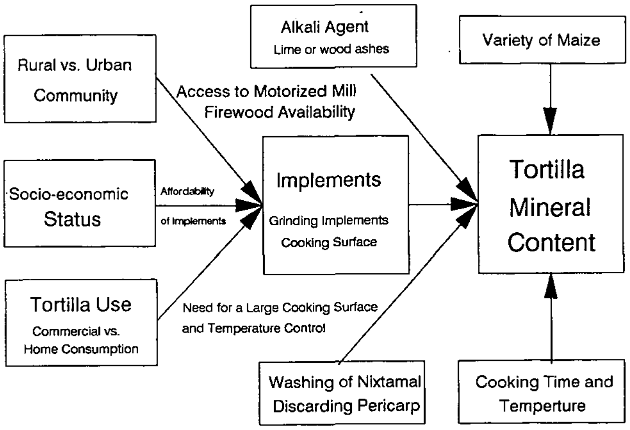
The tortilla, a flat-cake made of alkali-treated maize, is an important staple of the traditional Guatemalan diet. Alarcón and Adrino found that in 1987, the consumption of maize products accounted for 70% and 27% of total dietary energy in rural and urban Guatemalan communities, respectively (1).

In Guatemala, tortillas are made by boiling dried maize in a mixture of limestone (approx 1%) and water to separate the outer hull of the maize kernel and soften the grain (2). After being left to stand overnight, the limed-cooked maize (nixtamal) is washed and ground to form a soft moist dough (masa).

Finally, a small ball of masa is formed into a patty and cooked on a «comal», a surface of clay or sheet metal over an open fire. Reviews on the technology, chemistry and nutritional value of tortillas have recently been published (3,4).

We have previously reported that in Guatemala, the calcium, iron , and zinc contents of tortillas from rural areas appear to be higher than that of tortillas from urban centers (5). Figure 1 presents a theoretical framework of factors which may affect tortilla mineral content and account for the variation therein. Although the factors in Figure 1 were not all examined in this study, they should be kept in mind when interpreting the present results and planning future research.

FIGURE 1
Factors affecting tortilla mineral content



Socio-economic status may determine rural-urban variation in tortilla mineral content by influencing which implements can be afforded. People without the financial resources to pay for motorized milling may use the less costly hand-operated, stone grinding implements, the «mano y metate». Rural-urban variation may also be mediated by the presence of a motorized mill. The choice of cooking surface may be influenced by firewood availability.

Previous studies suggest that the most proximate factors influencing the mineral content of tortilla appear to be the variety of maize, the source of alkali, pre-soaking prior to nixtamalization, cooking time and temperature, and the extent of washing of the nixtamal (6,7,8). These factors have been examined primarily in relation to variation in the calcium content of tortilla.

The use of certain implements in the grinding of nixtamal may also affect the mineral content of tortilla. The «mano y metate» appear to enhance the iron and zinc content of traditional Hopi and Pima indigenous maize foods (9,10). Contributions to the mineral content of food could also result from the type of cooking surface used (11).

This paper examines variation in the mineral content of tortilla according to the implements used for making tortillas and inquires as to whether preparation effects might mediate rural-urban variation in tortilla mineral content.

MATERIAL AND METHODS

A. *Sample collection and interviewing*

This study was conducted during the pre-harvest season of June and July, 1987. Tortillas were collected from the female head of a total of 50 households of Kekchi indigenous people from three rural, two semi-urban and one low income urban community described previously (12).

The female head of each household was interviewed to determine:

- amount of maize prepared as tortilla on the day the samples were collected.
- type and source of maize and alkali agent, and source of water for tortilla-making.
- grinding implements, cooking surface, and pot used to prepare the tortillas.

One to five tortillas, depending on availability, were purchased from each household at their local value at that time, three to five tortillas for ten centavos. The tortillas were weighed individually on a balance accurate to within one gram, packaged into clean plastic bags, and maintained at -10° C until just prior to analysis. Tortillas were cooled to room temperature prior to weighing.

In 31 households, a sample of the lime used for tortilla preparation was also taken. Moist samples of lime were maintained at -10°C until just prior to analysis. Lime samples of a dry powdery nature were weighed, transferred to glass test tubes and maintained at room temperature. The amount of lime used per pound of maize was estimated in the following way: the tortilla-maker was asked to provide a sample equivalent in amount to that which she had used to prepare the batch of tortillas from which the samples were collected. This amount was divided by the number of pounds of maize used to prepare tortillas on the same day.

B. *Laboratory procedures*

Moisture analysis was performed on individual tortillas according to the method of the A.O.A.C. (13). Following moisture analysis, dry tortilla matter was pulverized with a porcelain mortar and pestle. For each of the 50 households, a composite sample was made by pooling the pulverized, dry tortilla matter from the tortillas of a particular household. Subsequent analyses were performed on aliquots of the composite samples.

Ashing was performed in a porcelain crucible. Approximately one gram of dry matter from a composite sample was ignited at 550°C for six hours in a Sybron Thermolyne Furnatro II furnace. Following ignition, crucibles were weighed to four decimal places on a Mettler AE 200 electronic balance.

Following ashing, the ash residue in the crucible was taken up in approximately one ml of concentrated HCL (Allied Chemicals) and quantitatively transferred to an acid-washed 10 ml volumetric flask. For iron, zinc and copper, the digests were diluted with double glass-distilled de-ionized water using an automated Hamilton dilutor (Microlab Model). For calcium, the final dilution was made with 1% lanthanum oxide. The dilutions were read on a Perkin Elmer atomic absorption apparatus (Model 2308) at the appropriate settings as specified by the manufacturer of the instrument (14). Standard solutions were prepared from Fisher Certified Atomic Absorption Reference Solutions.

Moisture, ash, and mineral analyses of tortilla were performed in duplicate analyses which agreed to within 5% for 80% of the analyses and to within 9% in the remaining 20%.

Procedures for ash and mineral analyses of lime were performed as for tortillas.

C. Data treatment

Analysis of variance was performed using the general linear model procedure of SAS on the mainframe computer at McGill University (15).

To analyze the relationships between aspects of preparation and tortilla mineral content, all variables and all possible interaction effects were entered into the full model. One by one the least significant variable was removed from the full model and the analysis was repeated on reduced models. The final models include only the implements used in preparation (grinding implement or cooking surface) since none of the interactions or other variables had significant effects.

RESULTS

All tortillas were made from white maize bought from local vendors. In 34 households that prepared tortillas exclusively for consumption by household members, the mean (±Std. Dev.) amount of maize prepared per person per day was 1.6 (±0.8) pounds. As previously published, the 50 tortilla samples were found to contain a mean of 1.6 g ash, 10.7 g crude protein, 202 mg calcium, 2.7 mg iron, 3.4 mg zinc, and 0.33 mg cooper per 100 g dry matter (5). A subset of six samples was found to have a mean crude fat content of 2.3 g, 4.7 g acid detergent fiber, 79.2 g total carbohydrate and 373 kcal pero 100 g dry matter. The mean moisture content of the 50 samples was 46.4%.

Types of implements used

As shown in Tables 1 and 2, the predominant types of implements used varied more between than within communities. A hand mill was used in some rural households whereas a motorized mill was commonly found in the semi-urban and urban areas. All but three of the 50 households reported to use the «mano y metate» to further refine the texture of the masa. The three households which used only the mano y metate on the day the samples were collected cited the prohibitive cost of the motorized mill (five to 25 centavos per batch of masa) as the reason for using the hand implements.

TABLE 1
RURAL-URBAN VARIATION IN THE TYPES OF GRINDING IMPLEMENTS USED IN TORTILLA-MAKING

Grinding Implements	Rural (n=15)	Semi-urban (n=21)	Urban (n=14)
Mano and Metate	1	0	0
Hand Mill & Mano and Metate	9	1	0
Electric Mill	2	0	1
Electric Mill & Mano and Metate	3	20	13

n= number of households from which tortillas were collected.

TABLE 2
RURAL-URBAN VARIATION IN THE TYPES OF COOKING SURFACES USED IN TORTILLA-MAKING

Cooking surface	Rural (n=12)	Semi-urban (n=19)	Urban (n=14)
Sheet metal	3	9	8
Barrel top	2	2	1
Clay	7	8	5

n= number of households from which tortillas were collected.

In rural areas, the clay comal was most common. In the semi-urban and urban areas, all women who prepared tortillas exclusively for home consumption used sheet metal or a barrel top. Only the 13 women who sold tortillas used a clay comal. Tortilla-makers reported a preference for the clay cooking surface because it provides a larger surface area and allows for greater temperature control. In the communities where firewood is less readily available, and usually purchased, sheet metal cooking surfaces seemed to be preferred because of their fuel efficiency.

Preparation effects on mineral content

Tortillas prepared with different types of grinding implements were found to vary significantly ($p<0.05$) in their iron and zinc content (Table 3). Grinding with the hand mill and «mano y metate» was associated with a significantly ($p<0.05$) higher iron content. The grinding bits in both the hand and motorized mills are made with wrought iron, a likely source of adventitious iron. The two tortillas ground only with the «mano y metate» had a significantly ($p<0.05$) higher mean zinc content. When tortillas are not also ground with a hand or motorized mill, the extent of grinding with the «mano y metate» is likely greater, thus accounting for the higher zinc content of tortillas ground exclusively with the «mano y metate».

TABLE 3
THE MINERAL CONTENT OF TORTILLA PREPARED WITH DIFFERENT GRINDING IMPLEMENTS

Grinding Implement(s)	n1	Iron	Zinc
		Mean±Std. Err. (mg/100g dry weight)	
Mano & Metate	2	2.5±0.5a	4.0±0.2a
Mano & Metate & Hand Mill	10	3.8±0.2b	3.2±0.1b
Motorized Mill	3	2.7±0.4a	3.4±0.2b
Motorized Mill & Mano y Metate	35	2.5±0.1a	3.5±0.05b
Model	50	F=7.76 p=0.0003	F=3.72 p=0.02

n1 = number of households from which tortillas were collected. Means in the same column with the same letter are not sig. different, p<0.05.

In five households, more than one type of cooking surface was used on the day the samples were collected. For this reason, these samples were excluded from the analysis of the effect of the cooking surface. Tortillas cooked on a barrel top had a slightly but not significantly higher iron content (Table 4). If indeed the cooking surface contributes iron, this effect may have failed to attain statistical significance because comparatively more iron was contributed by the grinding implements, thus overshadowing the effect of the cooking surface.

TABLE 4
THE IRON AND ZINC CONTENT OF TORTILLA PREPARED WITH DIFFERENT COOKING SURFACES

Grinding Surface	n1	Iron	Zinc
		Mean±Std. Err. (mg/100g dry weight)	
Sheet Metal	20	2.5±0.2	3.5±0.08
Barrel Top	5	3.3±0.4	3.4±0.16
Clay	20	2.9±0.2	3.4±0.08
Model	45	F=1.74 p=0.19	F=1.42 p=0.25

n1 = number of households from which tortillas were collected.

The pot used for nixtamalization and the source of water did not significantly account for variation in the content in tortilla of any of the minerals of note. None of the possible models for tortilla calcium for copper content were significant (not shown).

Alkali agent (lime)

Limestone was used as the alkali agent for the preparation of all tortilla samples. All households purchased lime locally at the market or store. Two households reported occasional use of wood ashes as a source of alkali. One household also used ground sea shells obtained from a local river. The higher price of lime was cited as the reason for using alternativa sources of alkali.

The mean and standard deviation for the quantity of lime used per pound of maize was 6.5±3.7 g. The mean ash content of all 33 lime samples was 83.6%. Calcium and iron comprised 39.6% and 16.7% of the dry weight of lime respectively. Zinc and copper were present only in trace amounts. Significant inter-community differences in the mineral content of lime were not found (not shown). Correlations between the amount of mineral in the quantity of lime used and tortilla mineral content were low and none were significant.

DISCUSSION

These results suggest that the use of certain grinding implements may mediate rural-urban variation in tortilla iron and zinc content. Kuhnlein and Calloway also found that fine grinding contributes manganese, phosphorous, a slight increase in calcium, and a seven fold increase in the iron content of traditional Hopimaize foods (9). Environmental factors such as firewood availability may explain the choice of cooking surfaces used in tortilla preparation. Brouwer et al. also describe changes in food preparation patterns as a coping strategy in the increasing firewood shortage in developing countries (16).

That grinding implements did not have a significant effect on tortilla calcium content is no surprise since the contribution of calcium from the lime-wateer likely overshadows other factors. According to Trejo-Gonzalez et al., the concentration of lime always exceds the saturation point of calcium hydroxide in water (8). Under such conditions one would not expect the calcium content of tortilla to be limited by the concentration of calcium in the cooking water, but rather by the capacity of the maize to take up calcium. Eighteen genetically different strains of maize were found to vary from 990 to 1690 mg/kg in their capacity for calcium uptake (8). Tortilla calcium content is also positively associated with the duration of steeping and cooking time (6).

The mean calcium content of the present lime samples (39.6%) is comparable with the value of 34% reported in the United States/Canadian Tables of Food Composition (17). In contrast, these tables report that limestone contains only

0.35% iron. Soil contamination may be responsible for the higher iron content observed in our samples. Bressani suggests that changes in the mineral content of tortilla during tortilla-making may be related to impurities and the nature of the lime used (3). As we observed only trace amounts of zinc and copper, this is not likely the case for these two minerals.

The role of the tortilla as a source of dietary minerals must be examined in the context of their bioavailability, and of other items in the diet. Solomons et al. have shown that when added to a test meal, tortilla inhibits the absorption of dietary zinc (18). Reinhold and García-López report that the fiber content of tortilla may also cause disturbances in absorption of calcium and iron (19). Further studies are required to determine the biological value of adventitious iron and zinc which appear to be contributed during the preparation of tortillas.

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