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Effect of the nixtamalization with calcium carbonate on the indigestible carbohydrate content and starch digestibility of corn tortilla

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ABSTRACT

There is a growing interest for an environment-friendly nixtamalization process. Nixtamalization with calcium salts generates a minimum level of polluting residues. The effect of a nixtamalization process with calcium carbonate (NCC) on the indigestible carbohydrate content and starch digestibility of tortillas was evaluated. Traditional and NCC tortillas showed lower moisture content than commercial tortillas. Similar protein, ash, and carbohydrate content were found for the three tortillas, but NCC tortillas showed the highest lipid content. The NCC tortilla had the highest dietary fiber content, with the highest insoluble dietary fiber level. Fresh and stored (96 h) NCC and traditional tortillas showed similar resistant starch content. Fresh traditional tortilla showed the highest slowly digestible starch (SDS), but upon storage the rapidly digestible starch (RDS) content of NCC tortilla decreased. Fresh traditional and NCC tortillas had lower predicted glycemic index (pGI) than commercial tortillas, and upon storage, the three tortillas presented lower pGI values than their fresh counterparts. Consumption of tortillas produced with the NCC can produce positive effects in the human health.

1. Introduction

Although dietary habits are changing, maize tortilla continues being the main staple food for Mexican people. The Aztecs nixtamalized maize using volcanic ashes (classic nixtamalization), and this practice changed with the substitution of these ashes by calcium hydroxide (traditional nixtamalization). Both nixtamalization processes include four main steps: cooking, steeping, washing of nixtamal, and grinding to obtain the masa (dough). Because the nixtamalization process generates large amounts of highly polluting residues, an alternative nixtamalization process using calcium carbonate (NCC) was developed (Campechano et al., 2012) where a minimum level of residues generated due to the types of calcium salts that are used (calcium sulfate, calcium carbonate, and calcium chloride). The salts are mixed with maize grains (1% w/w of maize grain), heated until the temperature reaches the boiling point of water, cooled down and steeped for 16 h; nixtamalized maize grains are washed to eliminate the excess of salts and ground to obtain masa, which is dried to produce nixtamalized maize flour (Mexican Patent 289339, Figueroa et al., 2011). The NCC process produces flour containing the majority of the maize components, among them non-starch polysaccharides present in the pericarp. Tortillas and other products (snacks, tostadas, tamales) made with this flour may have higher dietary fiber content than those products made with flour obtained by the traditional nixtamalization process. Our group has been studying the starch digestibility of tortilla because for many years it was thought that tortilla supplied an important amount of glycemic carbohydrates (Agama-Acevedo et al., 2004, 2005; Aparicio-Saguilan et al., 2013; Bello-Pérez et al., 2006; Grajales-Garcia et al., 2012; Hernandez-Uribe et al., 2007; Islas-Hernandez et al., 2006; Osorio-Diaz et al., 2011; Rendón-Villalobos et al., 2002; Sayago-Ayerdi et al., 2005). However, it was found that digestive enzymes do not hydrolyze all the starch present in

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tortilla and other amounts of starch are slowly hydrolyzed (Agama-Acevedo et al., 2004; Aparicio-Saguilan et al., 2013). Upon tortilla storage, starch digestibility decreased due to the formation of retrograded resistant starch and the non-starch polysaccharides arrangement that produced a barrier to starch hydrolysis by the digestive enzymes. These studies showed that tortilla had high glycemic index, but it was recently shown that the starch digestion rate is more important due to the health benefits brought by slowly digestible starches (Lee et al., 2013). The use of the NCC process to produce tortilla with all components of the maize grain could provide more nutraceutical benefits upon consumption, since more dietary fiber is present and the arrangement of these non-starch polysaccharides can limit the access of the starch-hydrolyzing enzymes. Therefore, the aim of this study was to evaluate the effect of NCC on starch digestibility of tortilla.

2. Materials and methods

2.1. Traditional nixtamalization process

Corn grain (commercial Celaya variety) was processed by the traditional method as follows: 10 kg was cooked with 20 L of water and 1.0% (w/w) calcium hydroxide at 90 °C for 23 min; cooked grains were steeped for 16 h at room temperature. The cooking liquor or nejayote was collected and the nixtamal was rinsed with water. The nixtamal was ground in a stone mill to obtain fresh masa. The masa was passed through a flash dryer at 260 °C for 4 s to obtain dehydrated flour. Subsequently, this flour was ground in a mill (Pulvex-200 México D.F. México) using a hammer head and then passed through a 0.5 mm mesh screen (Campechano et al., 2012).

2.2. Nixtamalization process with calcium carbonate

The method described by Figueroa et al. (2011) was used. The lime was replaced by calcium salts to obtain whole grain flour. Corn grain (10 kg) was cooked for 23 min with 20 L of water and 1% (w/w) of calcium carbonate salt; cooked grains were steeped for 16 h at room temperature. The pericarp-free water was separated from the grain and the liquor (nejayote) was eliminated. The nixtamal was milled in a stone mill to obtain the masa. The masa was dehydrated in a flash dryer at 260 °C, and ground using a hammer mill (Pulvex-200 México D.F. México) to pass a 0.5 mm mesh screen (Campechano et al., 2012).

2.3. Tortilla processing

Flours were hydrated to obtain masa which was molded by pressure and extruded with a commercial tortilladora (Model MOT-G, Tortilladoras González, Naucalpan, México) into thin circles to obtain 2 mm thick tortillas. Tortillas were cooked on a hot griddle for 1 min per side at 250 ± 5 °C. Texture analysis was done in tortillas and the *in vitro* digestibility tests were performed on powders obtained from freeze-dried tortilla. After cooling, tortillas were packed into polyethylene bags and stored for 96 h at 4 °C.

2.4. Chemical composition

The moisture content was determined by drying 2 ± 0.01 g of sample for 1 h at 130 °C, according to AACC 44-15 method (AACC, 2000). Ash, protein ($N \times 5.85$) and fat were assessed according to AACC methods 08-01, 46-13 and 30-25, respectively (AACC, 2000).

2.5. Soluble, insoluble, and total dietary fiber

The insoluble dietary fiber (IDF) and total dietary fiber (TDF) content were determined using the 32-05 AACC method. Soluble dietary fiber was calculated by difference: TDF − IDF.

2.6. Starch digestibility tests

2.6.1. Total, resistant and available starch

Total starch (TS) was measured according to method 76.13 (AACC, 2000). Briefly, 100 mg of sample were treated with 2 M KOH to disperse all starch fractions, which then were hydrolyzed by incubation with α-amylase and amyloglucosidase (AMG). Resistant starch (RS) was measured using the method 32-40 (AACC, 2000). The sample was incubated with pancreatic α-amylase and amyloglucosidase for 16 h to hydrolyze the non-resistant starch; then the reaction was stopped by the addition of ethanol. Finally, the samples were centrifuged to precipitate the RS. The pellet was then treated with 2 M KOH and hydrolyzed by incubation with AMG. Available starch was calculated as the difference between TS and RS.

2.6.2. Rapidly digestible and slowly digestible starch fractions

The rapidly and slowly digestible starch fractions were determined with the procedure proposed by Englyst et al. (1992).

2.6.3. Starch hydrolysis index of products "As Eaten" (chewing/Dialysis test)

The *in vitro* rate of starch hydrolysis was assessed with the protocol developed by Granfeldt et al. (1992) and reported for tortillas by Sayago-Ayerdi et al. (2005). Samples of tortilla equivalent of 1 g of total starch were tested. Data were plotted as degree of hydrolysis versus time curves, and the hydrolysis index (HI) was calculated as the area under the curve in an interval of 0–180 min and expressed as the percentage of the corresponding area obtained for commercial white bread, which was chewed by the same person. An average HI was calculated from six digestion replicates run for each sample. The predicted glycemic index (pGI) was calculated from HI values, using the empirical formula proposed by Granfeldt et al. (1992): $pGI = 0.862(HI) + 8.198$, for which the correlation coefficient (r) is 0.806 ($p < 0.00001$).

2.7. Statistical analysis

Results were expressed by mean ± standard error (SE). Differences among the means obtained in each of the determinations were evaluated by one-way analysis of variance (ANOVA), also a categorical multifactor experimental design (CMED) with two factors was used: type of tortilla (traditional, calcium carbonate, and commercial) and storage conditions (fresh and stored for 96 h). Least significant difference (LSD) with a significance level $p < 0.05$ was calculated. Statgraphics Plus version 5.1® (Manugistics, Inc., Rockville, MA, USA) was used.

3. Results and discussion

3.1. Chemical composition of flour and tortilla

The chemical composition of nixtamalized flours obtained with the two processes (traditional and NCC) and their tortillas is shown in Tables 1 and 2. There were only small differences in the composition between the two flours and their respective tortillas (Table 1). However, when both tortillas (traditional and NCC) were compared with a commercial tortilla, the difference in moisture content was more noticeable, which can be related to differences in the nixtamalization process and the maize variety used in the small