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The effect of different nixtamalisation processes on some physicochemical properties, nutritional composition and glycemic index

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ABSTRACT

The objective was to evaluate corn tortillas made from three nixtamalisation processes including Traditional with lime (TNP), Classic with ashes (CNP) and Ecological with Ca salts (ENP), and their effect on mineral content (Ca, Fe, K, and Mg), chemical composition, resistant starch (RS), and glycemic index (GI). ENP with calcium propionate and carbonate had higher fat values than tortillas from CNP. EPN and CNP presented the higher dietary fibre, explained by the highest pericarp retention. In TNP the pericarp and external layers were lost during the cooking, steeping and washing steps and had lower crude fiber. The amount of RS increased in nixtamal and tortillas independently of nixtmalisation processes. Annealing of starch was shown by the increase of onset, peak and final gelatinisation temperatures in nixtamalised products compared with untreated maize. Gelatinisation was higher for calcium propionate ENP and 1% ash CNP. Native maize changed from A-type to V-type pattern in nixtamalised products denoting the formation of amylose-lipid complexes. Overall, nixtamalisation processes and salts used increased RS. The GI was affected by chemical composition in tortillas and amount of RS. Tortillas made from ENP Ca propionate and ENP 1% ash CNP can be classified as low GI foods.

1. Introduction

Maize for human consumption is processed in Mexico following the pre-Columbian technique known as nixtamalisation which is a process whereby maize is boiled in water containing $Ca(OH)_2$ (lime), the *nixtamal* (cooked maize), obtained is steeped overnight, washed and ground to obtain masa. The masa can be used immediately for tortillas, or dried and grounded to produce dry masa flour (nixtamalised flour). The nixtamalisation process is critical in enhancing the nutritional value of maize and is used to make several products (tortillas, tamales, pozole, atoles, totopos, snacks, tacos, tostadas, and nachos) which are staple foods in Mexico, Central America and widely consumed in United States (Campechano et al., 2012; Figueroa et al., 2013).

Archeological evidence suggests that the ancient nixtamalisation process (Classic Nixtamalisation Process, CNP) used by the Mayas in the Preclassic period (1200-250 B C.) consisted in cooking maize with wood ashes (Katz et al., 1974). Later the Aztecs, settled in central Mexico around 1325 A.D. substituted ashes for lime, though it is not clear exactly when, creating the Traditional Nixtamalisation Process (TNP) that is remained used in present commercial operations.

There is a need to improve the sustainability of the TNP which uses large volume of water producing high dry matter losses (3–15%) in the nixtamal during the cooking and washing steps (Campechano et al., 2012). During the mentioned processing

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steps nutrients are lost, including vitamins, fat, protein, dietary fibre and some biological active compounds (Maya-Cortés et al., 2010; Campechano et al., 2012; Rodríguez et al., 2013). In addition, the *nejayote* (cooking solution) is an environmental pollutant due to its high alkalinity which also damages the processing equipment.

Recently, an Ecological Nixtamalisation Process (ENP) patented by Figueroa et al. (2011) addresses some of challenges of environmental and nutritional effects. The ENP replaces calcium hydroxide with commercially available calcium salts (e. g. calcium propionate and calcium carbonate). The masa and tortillas made from ENP had improved appearance and sensory properties compared to those from TNP. Maya-Cortés et al. (2010) reported that rats fed with ENP tortillas gained weight and had a high-protein efficiency ratio, suggesting that nutritional properties were improved by the ENP. Rodríguez et al. (2013) showed that degradation of the phenolic compounds and anthocyanins is inhibited with ENP process. Bello-Pérez et al. (2014) and Santiago-Ramos et al. (2015a) demonstrated that tortillas made from ENP had high content of non-digestible carbohydrates resulting in a low glycemic index.

For a large segment of the population in Mexico, tortilla is the most important source of protein, calcium and carbohydrates (Campas-Baypoli et al., 1999; Figueroa et al., 2003). Carbohydrates are the main fraction of tortillas with starch as its major component. It has been well stablished that a fraction of starch is resistant to digestive enzymes, passes through the small intestine and reaches the large intestine where it is fermented by colonic microflora, and it is referred as resistant starch (RS) (Asp et al., 1996). Readily digestible carbohydrates lead to a rapid increase in blood glucose levels and insulin secretion contributing to health conditions that increase the risk of diabetes. The Glycemic Index (GI) ranks carbohydrate-containing foods on how quickly and how much they elevate blood sugar levels. Foods with a low GI (<55) and high RS help to slow down the absorption of carbohydrates and prevent extreme fluctuations in blood glucose (Foster et al., 2002).

The resistance of starch granules to the activity of amylases may be enhanced by annealing the starch. This consists of keeping the starch in water for a long period of time at a temperature lower than the gelatinisation temperature; such conditions are met during the steeping stage in the nixtamalisation process (Figueroa et al., 2013).

Tortillas with high protein, lipids, fibre and resistant starch content can be produced by the ENP and CNP, which can provide nutraceutical benefits upon consumption, specifically a high content of non-starch polysaccharides which limits the access of starch hydrolyzing enzymes resulting in tortillas with low GI (Bello-Pérez et al., 2014; Santiago-Ramos et al., 2015a).

While there are few studies on Classic Nixtamalisation Process (CNP) (Pappa et al., 2010; González-Amaro et al., 2015), most authors have focused on TNP mainly on processing parameters as alkali concentration and cooking and steeping times (Trejo-Gonzalez et al., 1982; Gómez et al., 1992; Rodríguez et al., 1996). When wood ashes are used in CNP the resulting nixtamal, masa, flour and tortillas have a different profile in terms of mineral content (Pappa et al., 2010), dietary fibre and resistant starch compared to TNP and ENP.

The different compounds (lime, wood ash, calcium salts) used in the nixtamalisation processes appear to have different effects on the starch, protein and the other components of maize grain and on the physical and functional characteristics of masa, flour and tortillas. Therefore, the objective of this study was to evaluate the effect of three different nixtamalisation processes on the chemical composition, resistant starch content and digestibility of tortillas tortillas and glycemic index measured in humans.

2. Materials and methods

2.1. Raw material

Commercial hard endosperm white maize was obtained in a local market in Queretaro, Mexico. It was stored at 4 °C until needed for processing. The lime [$Ca(OH)_2$] and the salts calcium carbonate [$CaCO_3$] and calcium propionate [$Ca(CH_3-CH_3-COO)_2$] of 97–99% purity food grade. Wood ash was of oak trees (*Quercus agrifolia*) from Oaxaca, Mexico.

2.2. Traditional nixtamalisation process (TNP)

The TNP method of Campechano et al. (2012) was used. Briefly, 1 kg of maize was cooked with 2 L of water containing 1.0% (w/w) calcium hydroxide at 94 °C for 30 min, the cooked grains (*nixtamal*) were steeped for 16 h to reach room temperature and the nixtamal ground in a stone mill to obtain fresh masa. The masa was passed through a flash dryer (CINVESTAV Mexico) at 260 °C for 4 s to obtain dehydrated flour. Subsequently, this flour was ground in a hammer mill (Pulvex-200 Mexico D.F., Mexico) using a 0.5-mm mesh screen.

2.3. Ecological nixtamalisation process (ENP)

The ecological process patented by Figueroa et al. (2011) was used in which lime was replaced by calcium salts to obtain whole grain flour. Briefly, 1 kg of maize was cooked with 2 L of water containing 1% (w/w) of calcium carbonate or calcium propionate for 30 min, the cooked grains were steeped for 16 h to reach room temperature. The nixtamal was ground in a stone mill to obtain masa. The masa was dehydrated in a flash dryer at 260 °C (CINVESTAV Mexico) and ground in a mill (Pulvex-200 Mexico D.F. Mexico) using a hammer head and a 0.5-mm mesh screen (Campechano et al., 2012).

2.4. Classic nixtamalisation process (CNP)

Two CNP were used containing different wood ashes concentration (1% and saturated 33%). 1 kg of maize was cooked with 4 L of water containing either 1% or 33% (saturated) wood ashes) at 94 °C for 60 min and the cooked grains steeped for 16 h to reach room temperature. The nixtamal was ground in a stone mill to obtain fresh masa. The masa was processed in a flash dryer at 260 °C for 4 s (CINVESTAV Mexico) to obtain dehydrated flour. Subsequently, this flour was ground in a mill (Pulvex-200 Mexico D.F. Mexico) using a hammer head and a 0.5-mm mesh screen.

2.5. Tortillas elaboration

A sample of 250 g of dried flour was hydrated until obtain masa with adequately consistence. The masa was shaped into disks of 15 cm of diameter and 2 mm thick using a manual roller machine (Casa González, Monterrey, NL, México), and cooked on a griddle at 280 °C for 17 s on the first side, 50 s on the second, and 34 s on the first side again to allow puffing. The tortillas were cooled at room temperature until they reached 30 °C, and groups of five tortillas were packaged in polyethylene bags.

2.6. Pasting properties

A Rapid Visco-Analyzer (RVA) (3C Model Newport Scientific PTY LTD, Sydney, Australia) was used to determine the pasting properties from viscoamylographic curves according to the method reported by Narváez-González et al. (2006).