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High oil content maize: Physical, thermal and rheological properties of grain, masa, and tortillas

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ABSTRACT

The objective of this study was to assess thermal, rheological and quality properties of grain, masa (ground nixtamalized corn), and tortillas made with high-oil maize hybrids and compare them with landraces. Grains of high-oil hybrids were harder (flotation index 10–36) with high onset, peak and final gelatinization temperatures, which were reflected in lower masa and tortilla yield. However, the tortillas had higher oil content (3.2–4.5 g/100 g) than those made with landraces (2.9–3.0 g/100 g). Tortillas made with the yellow hybrids were softer (1.8 N). Pepitilla had the highest viscosity in grain, masa and tortillas, reflected in greater water absorption and masa and tortilla yield (1.61 kg/kg maize). A close relationship was found between G' and G'' and retained pericarp and oil content in masa; higher content of natural gums produced firmer masa with higher viscoelasticity. The high oil content in tortillas reduced their water absorption and starch swelling capacity but inhibited starch retrogradation, so they remained softer during storage.

1. Introduction

Maize (*Zea mays* L.) is the cereal that is most produced and consumed in Mexico. It is mostly used for making tortillas, which are still the most important component of the Mexican diet. Approximate per capita consumption in rural areas is 79.5 kg per year, while in urban areas it is 56.7 kg per year (SE-DGIB, 2012). Tortillas are made from fresh ground nixtamal (masa) or nixtamalized flour (dehydrated masa). To obtain nixtamal, maize is cooked in water with lime, steeped for 12–16 h and then washed and ground to obtain the masa (Flores-Farías et al., 2000) with which tortillas are made. The physicochemical, rheological and textural properties of the masa and the end quality of the tortillas depend on both maize type and conditions of the nixtamalization process. The lime acts on the components of the grain cell wall and converts the hemicellulose into soluble gums. Moreover, this thermal-alkaline treatment gelatinizes part of the starch, saponifies some lipids and solubilizes part of the proteins (Mendez-Montealvo, Sánchez-Rivera, Paredes-López, & Bello-Pérez, 2006). Changes in the texture of high-starch products are associated mainly with the phenomena of starch gelatinization and retrogradation. In the case of tortillas, retrogradation and rate of dehydration are the factors responsible for hardening, an undesirable characteristic since consumers prefer soft tortillas. To prevent hardening, gums and hydrocolloids are used, although the addition of pericarp, lipids and enzymes directly to the masa has also been proposed (Arámbula-Villa, Gutiérrez-Arias, & Moreno-Martínez, 2007).

During the thermal-alkaline treatment, lipids interact with amylose molecules, affecting starch physicochemical properties. Arámbula-Villa, González-Hernández, and Ordorica-Falomir (2001) reported that elimination of all free lipids from the masa produces tortillas of unacceptable quality. These same authors found that the addition of 0.5 g/100 g maize lipids to nixtamalized maize flour decreases the rate of dehydration and improves masa and tortilla texture. Moreover, Vidal-Quintanar, Love, and Johnson (2001) indicate that the presence of oil significantly improves tortilla

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firmness and chewiness. Recently, Vázquez-Carrillo et al. (2014) used hybrids with high oil content (HOC) and found that the tortillas had a softer texture and greater elongation, both recently made and stored for up to 72 h in refrigeration, relative to the tortillas made from maize with low oil content. Thus, they concluded that HOC maize varieties are a good option for making good sensorial and nutritional quality tortillas.

The objective of this study was to assess and compare the thermal, rheological and grain quality properties of grain, masa and tortillas of maize landraces with those of high oil content hybrid maize varieties.

2. Materials and methods

2.1. Biological material

The genotypes used in this study are presented in Table 1. All were grown in the 2009 spring–summer crop cycle on the experimental sites of the National Institute of Research in Forestry, Agriculture and Livestock (INIFAP).

2.2. Physical characteristics and oil content of grain

In grain, floatation index (FI), as an indirect measure of hardness (SAGARPA, 2002, p. 14–15), and percentage of pedicel, pericarp, germ and endosperm (González, 2009) were assessed. In grain and tortilla, oil was analyzed by method 30-25.01 (AACC, 2000).

2.3. Nixtamalization process and quality variables of nixtamal and tortilla

Nixtamalization consisted of cooking 100 g maize with 0.7 g $Ca(OH)_2$ and 200 mL water. Nixtamalization time was assigned in accordance with the flotation index (FI = 0–12%, 45 min; FI = 13–38%, 40 min; FI = 39–62%, 35 min; FI = 63–87%, 30 min; FI = 88–100%, 25 min). After cooking, the nixtamal was steeped for 16 h, and then washed with 200 mL water to discard the cooking liquid (nejayote) and ground in a stone mill to obtain a fine textured masa. To make the tortillas, 20 g portions of masa were pressed with a metallic tortilla press to make discs of approximately 15 cm in diameter; these were baked on a metal griddle at a temperature of 260 ± 10 °C for 17 s on one side to form a thin layer, 50 s on the opposite side, and finally 17 s on the side of the thin layer to allow it to inflate. The tortillas were cooled at room temperature, packed in commercial polyethylene bags and stored in a domestic refrigerator at 4 °C. The content of solids in the nejayote (cooking water), pericarp retained in the nixtamal, and masa and tortilla yield were measured Vázquez-Carrillo, Garcia-Lara, Salinas-Moreno, Bergvinson, & Palacios-Rojas (2011). Moisture in masa and tortillas was determined with AACC method 44-19.01 (AACC, 2000).

Table 1
Identification and origin of the genotypes studied.

Genotype	Type[a]	Provenance
Chalqueño	Landrace	Texcoco, Edo. México
Pepitilla	Landrace	Iguala, Guerrero
WPN (White Population from the Northwest)	HOC Hybrid	Cd. Obregón, Sonora
WPB (White Population from the Bajío)	HOC Hybrid	Cd. Obregón, Sonora
YPN (Yellow Population from the Northwest)	HOC Hybrid	Cd. Obregón, Sonora
YPB (Yellow population from the Bajío)	HOC Hybrid	Cd. Obregón, Sonora

[a] HOC: high oil content.

2.4. Grain thermal analysis

Thermal properties of the grain were examined using differential scanning calorimetric equipment (DSC1 STAR[e] System Mettler Toledo®) previously calibrated with indium standard using the method proposed by Narváez-González, Figueroa-Cárdenas, Taba, and Rincón (2006).

2.5. Viscoamylographic profile

To determine the viscosity profile of the ground grain, masa and tortillas, the AACC method 61-02.01 (AACC, 2000) was used with modifications proposed by Ménera-López, Gaytán-Martínez, Reyes-Vega, Morales-Sánchez, and Figueroa (2013). The samples were examined with a rheometer (Anton-Paar Model Physica MCR 101) equipped with an accessory for measuring viscosity (model ST24-2D). Each sample was prepared with 18 mL distilled water and 3 g of sample. The temperature profile used for the analysis was heating from 50 to 92 °C at a rate of 6 °C min^{-1}. The temperature was maintained at 92 °C for 6 min and cooled from 92 to 50 °C at a rate of 6 °C min^{-1}. This treatment was replicated on each sample. In the case of masa, the samples were previously dried at 45 °C for 24 h, ground, and sifted through a US 60 mesh.

2.6. Rheological properties: viscoelasticity

Samples of masa were examined with an Anton-Paar Modelo Physica MCR 101 rheometer with a system of parallel plates (PP25/S) 25 mm in diameter. The analysis was conducted in duplicate on portions of 3 ± 0.007 g masa with 50 g/100 g moisture. During the test, temperature was maintained constant at 25 °C. The methodology to measure viscoelasticity comprised two phases: First, the linear viscoelastic region (LVR) was determined with an amplitude sweep performed from 0.01 to 10% strain at a frequency of 1 Hz. The amplitude sweep showed that LVR for this material was between 0.01 and 1% strain. Therefore, the value taken was 0.1% constant strain. Second, a 0.1–10 Hz frequency sweep was performed with 0.1% constant strain. The values of G' (elastic module) and G'' (viscous module) were recorded with the software that comes with the equipment.

2.7. Tortilla texture

Breaking force was measured with a texturometer Brookfield® (model CT3, Middleboro, MA, USA). A 5 cm tortilla disc was placed between two 1 cm thick metal plates, which had a 2 cm diameter orifice; through this orifice passes a spherical accessory (19.05 mm in diameter). The accessory travels at a speed of 1 mm s^{-1}. When the sphere makes contact with the tortilla, the tortilla stretches until it breaks; this breaking point is known as maximum breaking force. The distance the sphere travels after making contact and before the tortilla breaks is called elongation and is reported in mm.

2.8. Statistical analysis

All of the assessments were duplicated under a completely randomized design. The results were analyzed with an analysis of variance (one-way ANOVA), means were compared by Tukey's test (the significance at $p < 0.05$ was determined), and simple correlation analysis was performed. All statistical calculations were done with SAS software for Windows, version 9.0.

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