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The tortilla making properties of two improved maicillo cultivars from Honduras

S.O. Serna-Saldivar, M.H. Gómez, F. Gómez [1], D. Meckenstock [2], C. Cossette and L.W. Rooney

Cereal Quality Laboratory, Soil & Crop Sciences, Texas A & M. University, College Station, TX.

SUMMARY. Grains of two improved maicillo hybrids *(Sorghum bicolor (L) Moench)* and their criollo (Landrace) counterparts grown at two farmsites in Honduras were lime-cooked and processed into table tortillas. Kernels from the criollos were less dense and softer than kernels from the improved cultivars. The improved maicillos had straw or red plant and glume colors while the criollos were less dense and softer than kernels from the improved cultivars. The improved maicillos had straw or red plant and glume colors while the criollos had purple colored plants with black or purple glumes. The soft textured criollo kernels required less cooking than their harder improved counterparts. Nixtamals cooked to contain 53-55% moisture were the most suitable for processing into tortillas. Both improved maicillos compared favorably with Sureño (used as positive control during processing). The criollos produced darker, less acceptable tortillas. Masa and tortillas from criollos darkened during lime-cooking especially during baking. All sorghums and their respective tortillas had similar chemical composition.
The improved maicillos bred in Honduras have a significantly improved plant and glume color with white pericarp. The sorghum improvement was also observed in the overall tortilla quality.

RESUMEN. Producción de tortillas a base de dos híbridos mejorados de sorgo cultivados en Honduras. Dos híbridos mejorados de sorgo (*Sorghum bicolor (L) Moench*) y el sorgo criollo original (Landrace) cultivados en Honduras fueron nixtamalizados a fin de producir tortillas. Los granos de sorgo criollo original tuvieron una densidad más baja y fueron más suaves que los granos de sorgo híbridos mejorados. Los sorgos híbridos mejorados provenían de plantas de color claro y contenían glumas de color marrón claro, mientras que el sorgo criollo original provenía de plantas de color morado y contenía glumas de color negro. Los sorgos suaves fueron cocidos por menos tiempo que los sorgos duros. El grano cocido o nixtamal con una humedad de 53-55% fue procesado en tortillas. Los híbridos mejorados de sorgo produjeron tortillas comparables a las tortillas de Sureño (sorgo utilizado como control). El sorgo criollo original produjo tortillas oscuras de calidad no aceptable. La masa y tortillas producidas a partir de sorgo criollo original se fue oscureciendo durante el proceso especialmente durante el horneado de las tortillas. La composición química de los sorgos y sus respectivas tortillas fue similar en todos los casos.
Los sorgos híbridos cultivados en Honduras provocaron un notable mejoramiento en el color de la planta, glumas y pericarpio. Este mejoramiento fue luego observado en la calidad de las tortillas.

INTRODUCTION

Sorghum is the fifth most important cereal in total world production (1). The crop is well adapted to grow in hot, dry, semi-tropical areas of Africa, Asia and the Americas (2). The main use of sorghum in Latin America is for feed grain and forage. However, sorghum is used for production of tortillas and related products when maize is scarce or unavailable. The INTSORMIL/ICRISAT/Texas A & M and National Agricultural Research Groups in Sorghum Improvement Programs in Honduras, El Salvador, and Guatemala have released several white sorghum varieties and hybrids (i.e Dorado, tortillero, Sureño, Catracho) with improved tortilla making properties. Recently, the Honduran Breeding Program has focused on the improvement of photosensitive maicillo criollos which are traditionally cultivated for both forage and grain on hillsides throughout Central America. Maize and sorghum are interplanted. During droughts, peasants often relay on sorghum for tortillas.

The purpose of this study was to compare, under pilot plant

1 INTSORMIL Programa Internacional de Sorgo y Mijo. Escuela Agrícola Panamericana de Recursos Naturales, Honduras.
2 Sorghum Breeder, Soil & Crop Sciences, Texas A & M University

conditions, the tortilla making properties of Sureño (positive control) with two improved maicillo hybrids and a maicillo criollo grown under the same environmental conditions.

MATERIAL AND METHODS

Sorghum samples.

Two improved food grade maicillos (DM 197 and DMV 179), one native maicillo (Landrace) and an improved white sorghum variety (Sureño) were compared. The sorghum cultivars were grown at three different locations (Los Espaveles, Tablones Arriba, and Namasigue) in local farmer fields near Choluteca, Honduras in 1990 (Table 1) The individual samples were analyzed. The quality was similar at both locations for DMV-179 and at three locations for the criollos so the data presented are the mean of data obtained for each location.

TABLA 1
PEDRIGREE, LOCATION GROWN AND PHYSICAL PROPERTIES OF SORGHUM GRAINS (a)

Property	DMV-197	DMV-179	Criollo	Sureño
Pedigree	TAM 428* Porvenir 29	SPV 436* Gigante	Unknown	——
Location grown	Espaveles (Honduras)	Espaveles and Tablones Arriba (Honduras)	Espaveles, Tablones Arriba, and Namasigue (Honduras)	Halfway (Texas)
Pericarp color	White	White	White	White
Plant color	Red	Tan	Purple	Tan
Pericarp thickness	Thin	Thin	Thick	Thin
1.000 kernel Weight (g)	22.2±0.4	2.58±0.4	25.1±0.6	31.3±0.4
Test weight (lb/bu)	61.1±0.1	60.2±0.1	58.3±0.1	61.7±0.1
Density (g/cc)	1.37±0.005	1.38±0.005	1.35±0.005	1.37±0.006
Hardness (% removal)(b)	15.4±0.7	17.2±0.1	26.0±0.6	12.7±0.4
Endosperm texture(c)	1.5	1.5	3.0	2.0

(a) Values are means of 3 replications ± standard deviations.
(b) Estimated as amount of material abraded in a TADD MILL. The higher the value the softer the grain.
(c) Subjectively rated on the scale of 1 to 5, where, 1=hard endosperm and 5=soft endosperm.

Chemical composition.

Moisture and ash contents were determined by drying (101°C) and ashing (500°C) to a constan weight using standarized procedures (4). Protein (N x 6.25) was determined by Kjeldahl digestion and assayed with a colorimetric procedure for ammonia (10). Starch was measured by an automated colorimetric method involving hexokinase. Samples were autoclaved and hydrolyzed with amyloglucosidase (Diazyme L-200; Miles Lab., Inc., Elkhart IN).

Physical properties.

Grain density was determined using a nitrogen comparison multipycnometer (Model MUP-1S/N232; Quantachrome Corp., Syosset NY). Hardness was indirectly measured by decorticating grain samples (20 g) for 4 min in a Tangential Abrasive Dehulling Device. The amount of grain abraded was negatively related to hardness (reference).

The color of raw whole and decorticated grain flour, masa and tortillas was determined with a Hunter Lab. Colorimeter standarized with the following tiles: L=91.77; a= -11.07; b=1.36).

Pericarp, glume and nixtamal colors and pericarp thickness were subjectively evaluated. In addition, endosperm texture was rated subjectively on 10 randomly selected kernels cut in halves. Pericarp removal was evaluated on kernels subjected to 20 min lime-cooking at boiling temperature with subsequent steeping for 5h. The resulting nixtamals were stained with eosine Y and methylene blue and washed with methanol. Amount of pericarp removal was rated on the scale of 1 to 5 as previously described by Serna-Saldivar et al (5). Tortilla texture was subjectively determined by rolling a 1 inch wide tortilla strip around a 1 inch diameter dowel. Degree of breakage was graded on a five point scale where 1=breakage and 5=no breakage).

Masa particle size was determined by the fractionation scheme described by Gomez (6). Five grams of masa were suspended in 20 ml distilled water and sieved through a set of 850, 425, and 150 µm mesh sieves. The fractions retained on each sieve were dried, weighed and expressed as % of original sample weight (db).

Lime cooking properties.

Sorghum kernels (100 g each) (four samples) placed in perforated nylon bags were lime-cooked in a steam kettle (Model TDC/2-20, Grown Div., Dover, Corp., Elk Grove IL) at boiling temperature for 0,2,4 and 6 min and then steeped for 5h. The lime-cooking solution contained 50 L water and 83.3 g lime. Duplicate samples of each sorghum were cooked at each assigned cooking time. They were sequentially added for the predetermined cooking schedule. The last set of samples (0 min cooking) was added for the predetermined cooking schedule. The last set of samples (0 min cooking) was added after the steam was cut off so they were only steeped in the hot lime solution. During steeping the temperature decreased at a rate of 0.15°C/min. Nixtamal moisture content and dry matter losses were determined using the method developed by Serna-Saldivar et al (7). The cooking time required to bring the sorghum nixtamal to 51-52% moisture was predicted using simple linear regression. Almeida-Dominguez et al (3) indicated that sorghum nixtamal with 51-52% moisture content had acceptable process properties.

Pilot plant tortilla production.

Twelve kilograms of grain, including 3 kg samples of the different sorghums were placed into large perforated nylon bags and steam-cooked in 50 L water and 83.3 g lime. The alkaline-cooking of sorghum at boling temperatures resulted in overcooked nixtamals, eventhough when the cooking time was zero min. Therefore, special conditions were set up for the sorghum cooking. The lime solution was initially heated to 45°C and then sorghum samples were added. The steam flow rate was controlled to increase temperature at the rate of 1.9° C/min; therefore, reaching 90°C in 23-24 min. Steam flow rate was then regulated to maintain a temperature of 90-91°C for the pre-determined cooking time (Table 2). Nixtamal moisture ranged from 50.5 to 55.5%. These moisture contents provided acceptable nixtamal properties for grinding, sheeting and baking.

TABLE 2
THE NIXTAMAL PROPERTIES AT OPTIMUM-COOKING TIEME AND TEMPERATURE FOR THE FOUR SORGHUM CULTIVARS

Property	DMV-197	DMV-179	Criollo	Sureño
Optimum cooking Time (min)[a]	20	10	6	20
Steeping time (hr)[b]	8-12	8-12	8-12	8-12
Nixtamal color[c]	2.5	2.0	2.5	2.0
Pericarp removal[d]	3.0±0.0	2.5±0.5	3.0±0.3	1.7±0.2
Nixtamal moisture (%)	50.8±1.3	52.8±1.5	50.5±11.6	55.5±1.2
Dry matter losses (%)	5.0±0.5	5.4±1.0	3.0±0.3	4.6±0.4

(a) The cooking temperature was 90°C
(b) The temperature of the lime solution decreased at 0.15°C/min until equilibrated to room temperature during the steeping.
(c) Subjectively evaluated on the scale of 1 to 5, where 1=good (light-clean yellow) and 5=poor (dark-stained).
(d) Subjectively evaluated on the scale of 1 to 5, where 1=all pericarp removed and 5=all pericarp attached to the grain.

After cooking, steam was cut off, and grains were steeped overnight (8-16hr). Preliminary studies indicated that a steeping time of 5-6 hr is enough to fully hydrate the sorghum nixtamal. After steeping, the cooking liquor was discarded and the nixtamals washed with tap running water in perforated buckets to remove excess lime and detached glumes and pericarp tissue.

The clean nixtamal was stone ground (12 in. diameter lava stones) into masa using a 20 hp commercial grinder (Model CG, Casa Herrera Inc., Los Angeles, CA). Water was added during grinding at the rate of 0.4 L/min to increase masa moisture content to about 56-57% and to avoid excessive stone wear. For all runs, the gap between stones was adjusted to the same setting so to produce a fine masa suitable for table tortillas. The resulting masas were first blended for 3 min in a Hobart Mixer and then continuously sheeted and formed into tortilla disks with commercial equipment. (Model CH4-STM, Superior Food Machinery, Inc., Pico Rivero, CA). Tortilla thickness was indirectly controlled by producing 35±0.25 g of masa. Then, masa disks were conveyed into a triple pass gas-fired oven (Model CO440, Superior Food Machinery). Tortillas were baked for 49 sec at an average temperature of 288°C and cooled for 60 sec in a three stage cooling conveyor (Model 3106-INF, Superior Food Machinery). Tortillas were allowed to further equilibrate at room temperature for about 10 min, weighed, and packed in low density polyethylane bags.

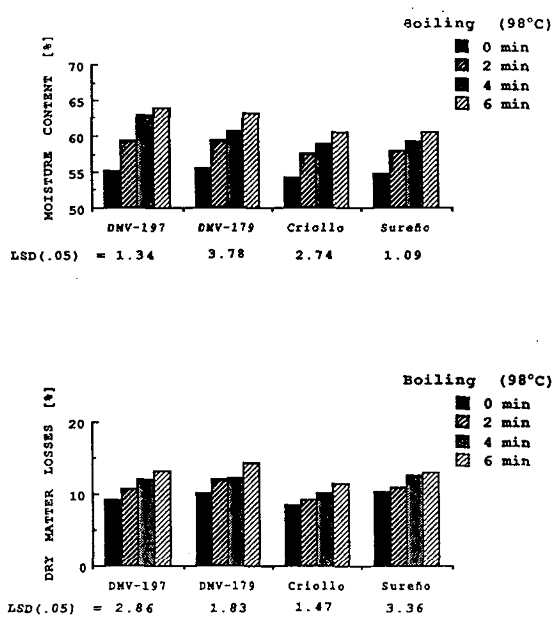
RESULTS AND DISCUSSION

All cultivars had white pericarps. Improved maicillo DMV-179 and Sureño had tan plant color and straw glumes. The other improved maicillo, DMV 197, had red plant and glume colors. The maicillo criollo had purple plant and glume colors (Table 1). The improved maicillo cultivars produced kernels with harder endosperm and thinner pericarps than the native criollo population. The thick pericarp in criollo kernels gave a more chalky appearance.

DMV 197 had the smallest kernels whereas the criollo and DMV 179 had similar 1.000 kernel weight (Table 1). Kernels from Sureño were heavier than the other kernels. Both improved maicillos had higher test weights, densities and hardness values than the criollo indicating that the breeding process has successfully produced grains with harder endosperms that are more suitable for tortilla production. With the exception of 1.000 kernel weight, the improved maicillo cultivars had physical grain properties similar to Sureño. Almeida-Dominguez (3) also found that a composite maicillo criollo sample contained smaller, softer kernels than Sureño and other improved Central American food sorghum types.

Nixtamal moisture content and dry matter losses increased with longer lime-cooking time (Fig. 1). The synergstic effect of temperature and exposure time increased both indices. Sorghum nixtamal with 51-52% moisture produced the best masa and tortillas. Nixtamal with <50 and> 55% moisture produced crumbly (non cohesive), and sticky masa after stone grinding, respectively. All sorghum types contained more than 50% moisture when they were cooked at 98° C for 0 min and steeped for at least 5 hr indicating that holding at boiling temperatures overcooked most of the grains. Cooking trials at 85, 87.5 and 90° C were conducted to prevent overcooking. A linear relationship between nixtamal moisture content and cooking time was found during cooking at 90°C. Cooking at lower temperatures produced a non-linear relationship difficult to interpret. Hence, cooking at 90° gave best results from the processing viewpoint. Improved cooking requirement of the criollo was closely related to its softer endosperm texture and lower hardness value (Table 1). Similar trends were observed by Almeida-Dominguez et al (3) who tested and compared 13 different sorghum types.

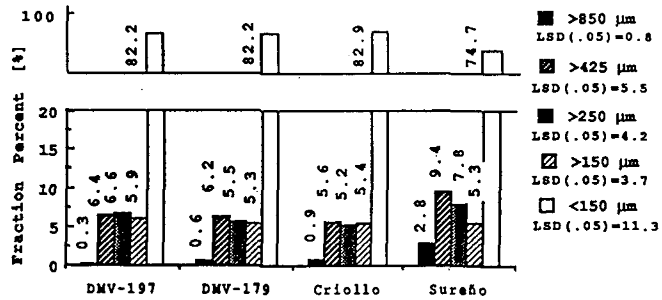
FIGURE 1
Nixtamal moisture content and dry matter losses of nixtamal cooked al 98 °C for 0,2,4 and 6 min.



Results of the pilot plant cooking trials are summarized in Table 2. DMV 197 and Sureño had comparable cooking requirements. The soft maicillo criollo required a lower cooking temperature and cooking time. The dry matter losses of sorghum cookied at 90°C ranged from 3,0-5.4% which are significatly lower than losses observed when cooking maize. Dry matter losses were mainly related to the amount of pericarp removed during cooking. The three maicillos had comparable pericarp removal values and were higher than the dry matter losses of Sureño.

Nixtamals were ground into fine masa suitable for table tortillas. All sorghums had similar yields of different masa fractions (Fig. 2). The most important fraction is the one that passes through the 150 µm screen because it is mainly composed of free native and partially gelatinized starch granules which are required to impart proper masa texture. The three maicillos have almost identical masa fractionation values and excellent masa machinability.

FIGURE 2
Particle size of sorghum masas cooked optimally and ground under standard conditions



Tortilla color, viasually determined, showed that the tortilla made from the criollo sorghum had the worst appearance due to its gray-dirty like color (Table 3). All sorghum tortillas had acceptable rollability immediately after baking. However, one day storage at room temperature caused significant firmness in tortillas, being DMV-197 and Sureño tortillas the most flexible. The others were too stale to roll without breaking. Tortilla mositure contents and pH were similar. The degree of starch gelatinization in tortillas, measured as enzyme susceptible starch, and tortilla moisture content were similar among sorghums and table tortillas obtained from maize (8,9). The criollo produce slightly more tortillas per kilogram of raw grain likely due to its lower dry matter loss. Tortilla yields are very comparable to yields obtained from maize and sorghum (3).

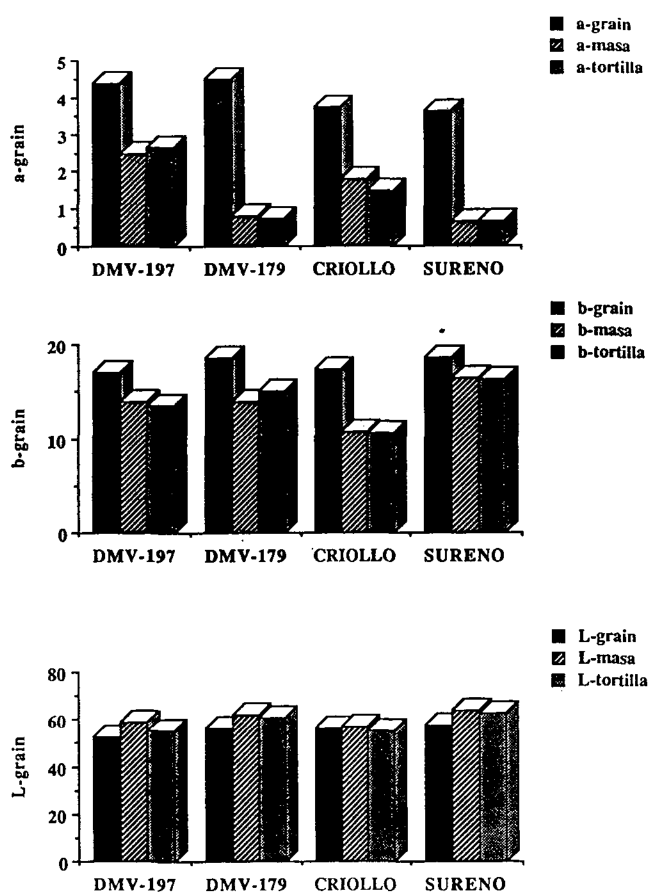
TABLE 3
EFFECT OF SORGHUM GENOTYPE ON THE PROPERTIES OF TORTILLAS

Property	DMV-197	DMV-179	Criollo	Sureño
Color (a)	3.0±0.3	2.0±0.5	4.0±0.6	2.0±0.3
Texture(b)	1.2±0.3	2.9±0.6	2.5±0.2	1.0±0.0
Moisture (%)	41.7±0.8	4.18±0.5	42.0±0.4	42.5±0.5
pH	8.2±0.1	8.0±0.1	7.8±0.2	8.2±0.0
ESS(c) (g glucose/g dry tortilla)	766±20	759±18	759±15	738±19
Tortilla yield (Kg tortilla/Kg grain)	1.47±0.05	1.48±0.08	1.52±0.09	1.41±0.02

(a) Subjectively evaluated on the scale of 1 to 5, where 1=good (light-clean yellow) and 5=poor (dark-stained).
(b) Tortilla rollability subjectively evaluated on the scale of 1 to 5, where 1=breakage and 5=no breakage.
(c) Enzyme susceptible starch ratio. Values provide an indication of starch gelatinization. The raw grains had values of less than 280 mg glucose/g dry sample.

Color of nixtamal, masa and tortillas was the factor that varied the most. DMV-179 and Sureño produced the best colored nixtamal, masa and tortillas. These sorghums had white pericarp and tan plant and glume color. DMV-179 and Sureño produced the whitest (high L value) and yellowest (high b value) tortillas (Fig. 3). The other improved maicillo criollo with red plant color and glumes produced better looking tortillas than the criollo (purple glume color) confirming that glume or plant color plays a critical role in tortilla acceptability. Phenolic compounds present in the pericarp, glumes and damaged areas of weathered kernels darken during lime-cooking. Glumes still attached to the pericarp leach their pigments into the kernel producing a dirty colored masa which darkened even more during baking.

FIGURE 3
Color of nixtamal, masa and tortilla



The chemical composition of the improved maicillos was comparable to that of criollo and Sureño grains (Table 4). Therefore, the genetic improvement did not have any major effect on the overall chemical composition.

TABLA 4
CHEMICAL COMPOSITION OF SHORGHUM GRAINS AND TORTILLAS $^{(A)}$

Cultivar	Protein (N x 6.25)	Ash (%)	Fat (%)	Carbohydrate (%)
DMV-197				
Grain	10.6±0.0	1.8±0.1	2.4±0.2	81.1±2.8
Tortilla	11.9±0.2	1.7±0.1	2.1±0.1	79.7±0.7
DMV-179				
Grain	9.8±0.1	2.0±0.1	2.2±0.3	82.2±1.2
Tortilla	10.8±0.3	1.8±0.1	1.9±0.2	79.4±1.1
Criollo				
Grain	9.6±0.1	1.8±0.1	2.4±0.3	79.8±0.3
Tortilla	10.8±0.3	1.7±0.1	2.1±0.2	79.2±0.4
Sureño				
Grain	10.4±0.2	1.8±0.1	2.2±0.2	78.5±0.8
Tortilla	11.0±0.1	1.7±0.1	2.3±0.1	79.2±0.5

(a) Values are expresses on dry basis

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