Thin Porridges (*Atole*) Prepared from Maize and Sorghum[1]

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ABSTRACT

Thin porridges (*atoles*) were prepared from food-grade white maize or white sorghum using modified traditional methods. Flours and *atoles* were prepared in the laboratory from roasted, nixtamalized, or steeped grains. Sorghum was decorticated 10% before processing. Experimental flours and *atoles* were evaluated for their physical, chemical, and organoleptic properties. *Atoles* prepared by roasting or nixtamalization from both grains had pleasant roasted and nixtamalized flavors and aromas. *Atoles* prepared by steeping had bland flavors that were less acceptable than roasted and nixtamalized flavors. Consistency of *atole* was affected by preparation procedure, starch content, and extent of starch gelatinization or dextrinization. Maize flours and *atoles* had larger particle sizes and coarser textures compared to sorghum products. Good quality, acceptable *atoles* were prepared from white maize or white sorghum.

Thin porridges (creamy, free-flowing beverages) are traditional products in many African and Central American countries. In many areas of Africa where sorghum is the staple food, thin porridges are prepared from sorghum flour (Vogel and Graham 1978). In Central America, thin porridges or *atoles* are traditionally prepared with maize; however, in some regions of Honduras and El Salvador, sorghum is used for *atole* preparation (Futrell and Jones 1982, Herrera 1982). *Atole* is prepared from wet-milled pastes or dry-milled flours after various treatments, i.e., cooking, roasting, nixtamalization, and steeping processes (Figs. 1 and 2). The organoleptic characteristics of *atole* are affected by the treatment given to the grain before milling, grinding efficiency, type of grain, and the spices added to improve palatability. In Mexico four different kinds of *atole* are popular (Table I). In Central America, *atoles* are traditionally served for breakfast or to lactating mothers and young children.

High-yielding sorghums with good grain quality are becoming available (Doggett 1982, Jimenez and Hurtado 1984) and should be evaluated for their processing qualities into traditional cereal products, i.e., *atoles*, tortillas, and snacks (Bedolla 1983, Sidney and Roberts 1967). The objectives of this work were to standardize laboratory procedures to prepare *atole* flours from maize and sorghum, to characterize some physicochemical properties of flours and *atoles*, and to determine the organoleptic characteristics of maize and sorghum *atoles*. The use of sorghum for *atole* preparation would provide low-cost, alternative products in areas where supplies of the traditional crop (maize or wheat) are insufficient to feed growing populations.

MATERIALS AND METHODS

Grain and Flour Samples

A white sorghum, CSH-6, grown at Halfway, Texas, in 1980, and a white commercial, food-grade dent maize hybrid (Asgrow 405; purchased from Asgrow Seed Co., San Antonio, TX, in 1983) were processed into experimental *atole* flours and *atoles*. The sorghum was decorticated for 2.5 min in an abrasive mill (Reichert 1982) until approximately 10% of the original kernel weight was removed. The decorticated sorghum was separated from the pericarp and fines using a South Dakota seed blower. The weight of the clean decorticated grain was recorded as percent milling yield.

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Procedures to Prepare Maize and Sorghum *Atole* Flours

Pinole—Roasting. Pinole flour was prepared by roasting and then dry milling grain (Fig. 1). The traditional process was modified by using decorticated sorghum and different mills. Maize and decorticated sorghum samples (100 g) were placed in round cake pans (20.3 × 3.8 cm) and roasted at 232° C for 10 min in a reel oven (Reed Oven Co.). The above roasting parameters were selected after optimizing conditions between 204–260° C and 5–12 min. The physical and functional properties of experimental flours and pinoles were compared to commercial maize products. The roasted grain was milled into flour using a small attrition mill (Kitchenetics Co., Campbell, CA). Maize required grinding into a coarse meal (burr mill, Straub Co., Philadelphia, PA) before flour production to yield a similar particle size distribution as commercial maize pinole.

Atole from masa—Nixtamalization. The traditional process of making *atole* from masa (Fig. 2) was modified to attain a dry flour with appropriate characteristics. Nixtamalized *atole* flour was prepared by cooking the grain in lime, steeping, drying, and grinding. Grain (1,500 g) was nixtamalized using conditions described by Choto et al (1985). After nixtamalization, only maize was steeped (3 hr). The *nixtamal* was dried in a reel oven at 55° C (20 hr for maize; 14 hr for sorghum). The dried *nixtamal* was milled into flour using the same procedures described above. The flours were sieved through a U.S. standard sieve no. 40 to remove particles larger than 420 μm.

Atole—Steeping. The traditional process of making *atole* was interrupted to attain a dry flour (Fig. 2). Grain (1,500 g) was steeped at 25° C for 49 hr with running tap water. The steeped grain was washed, drained, and wet milled using a procedure similar to that for nixtamalized samples. Water was added during wet milling at the rate of 1,800 ml of water per 100 g of dry grain. The slurry was wet sieved through a U.S. standard sieve no. 40 with an additional 1,000 ml of water per 100 g of dry grain. The slurry was allowed to stand for 2 hr before the excess water was discarded. The remaining paste was spread on baking trays and placed in an oven at 50° C for 30 hr. Dried samples were milled in a small attrition mill to break agglomerates formed during drying.

Raw Grain Flours Preparation

Raw maize and decorticated sorghum were milled to flour using a small attrition mill. Maize required grinding into a coarse meal before flour production to yield a smaller particle size distribution. Both flours were sieved through a U.S. standard sieve no. 40.

Physical and Chemical Characteristics of *Atole* Flour

Some physical and chemical characteristics of experimental *atole* flours were determined, i.e., particle size, pH, moisture, protein, protein digestibility, starch, enzyme-susceptible starch (ESS), and amylograph cooking properties. Particle size of *atole* flours was determined by the method reported by Bedolla and Rooney (1984) using a 30-g sample. The particle size index (PSI) was calculated using the following equation:

$$PSI = (1/\text{Total recovery}) [(Wt_i)(K_i)]$$

where Wt_i represents the weight on each U.S. standard sieve (nos. 25, 40, 60, 70, 80, and pan) and K_i is the factor (25, 40, 60, 70, 80, and 100) for each sieve, respectively.

Moisture content and pH of flours were determined (AACC 1976). Crude protein (N × 6.25) was determined using the micro Kjeldahl method with an autoanalyzer system (Technicon 1976). True protein digestibility was determined (Pederson and Eggum 1983). Starch content and ESS were determined (Technicon 1978). The cooking viscosity of *atole* flour was determined using a Visco-Amylograph (type VAV, model 3042, Brabender Instruments, Inc., South Hackensack, NJ). Amylograph conditions were: 700-mg sensitivity cartridge, 75 rpm, 500 ml bowl, heating at 1.5°C/min from 25 to 95°C, holding 20 min at 95°C, and cooling at 1.5°C/min from 95 to 50°C. The amount of flour used was 12% (db) for roasted and nixtamalized samples and 6% (db) for raw and steeped grain samples.

Atole Preparation and Characterization

Atoles (100 ml) were prepared at flour-sugar-water ratios (w/w/v) of 1:0.7:15, 1:0.8:25, and 1:0.9:28 for roasted, nixtamalized, and steeped grain flours, respectively. *Atole* from the control, raw grain flour, was prepared using the same proportion of ingredients as the steeped sample. Flour was suspended in 20 ml of cold water and then poured into a 250-ml beaker containing 80 ml of water at 95°C. The mixture was cooked with constant stirring for 3 min on a hot plate set at 6 (approximately 350°C, empty). Sugar was added approximately 1 min after adding the flour.

Taste panel evaluations were conducted on *atole* prepared from roasted *atole* flour and from fresh nixtamalized and steeped grain slurries using the above ratios. The apparent viscosity (η_{app}) of *atole* was measured using a rational viscometer (model RTV with a small sample adapter, Brookfield Engineering Lab., Inc. Stoughton, MA). The apparent viscosity was calculated using the following equation:

$$\eta_{app} = \text{Calibration factor (scale reading/50 rpm)}$$

where the calibration factor was 108 cP. Apparent viscosity of *atole* was also determined using a gravity-flow method (Diehl 1982). The *atole* sample (50 ml) was allowed to flow through a pipette (2.0 mm i.d.) by gravity. Distilled water required 8 sec to flow through the pipette.

Organoleptic Evaluation of *Atoles*

Untrained panelists from Latin America evaluated *atole* samples for acceptability and preference. A nine-point balanced scale for acceptability (1 = like extremely, 9 = dislike extremely) was utilized.

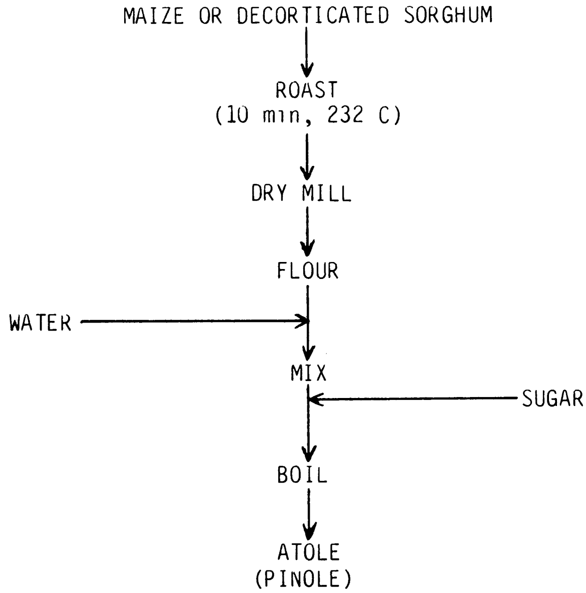

Fig. 1. Laboratory procedure to prepare roasted *atole* (*pinole*) from maize and decorticated sorghum.

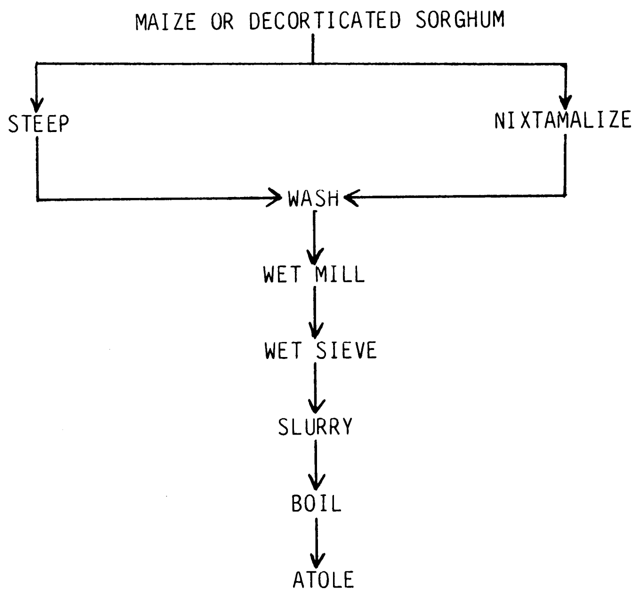

Fig. 2. Laboratory procedure to prepare nixtamalized or steeped *atoles* from maize and decorticated sorghum.

TABLE I
Traditional Preparation of *Atoles* from Maize in Mexico[a]

Traditional Name (Mayan name)	Grain Treatment	Subsequent Processes
Pinole (*Kah*)	Roasting—Mature grain is roasted in frying pan for 3–15 min.	Dry milled into flour using small burr grinder. Spices (cinnamon and/or anise) and brown sugar are added during milling. *Atole* is prepared with flour and water or milk and boiled for 4 min.
Atole from masa	Nixtamalization—Mature grain is cooked in lime and steeped as in tortilla preparation.	Wet milled in small burr or stone grinder (*molino*). Masa is wet sieved to remove larger particles. *Atole* is prepared from the slurry and boiled for 15–20 min.
Atole nuevo (*Ak-Sa*)	Immature maize is harvested at the dough stage and threshed.	Wet milled in small burr or stone grinder. The wet paste is sieved to remove pericarp and large particles. *Atole* is prepared from the slurry by boiling for 15–20 min.
Atole (*Ishul*)	Steeped—Mature maize is soaked in fresh water for 48 hr at 30–35°C.	Wet milled in small burr or stone grinder. The wet paste is sieved. *Atole* is prepared from the slurry by boiling for 15–20 min. Spices (orange leaves and cinnamon) and sugar are added during cooking.

[a] Personal communication with citizens of Mexico (1986).

Statistical Analysis

Three observations were recorded from each of two replicates. Analysis of variance (ANOVA) on a 2×4 factorial experimental design was used to test for differences between experimental *atole* flours or between atoles. Duncan's multiple range test and least significant difference analyses were used to calculate differences among means for physical, chemical, and organoleptic characteristics of flours and atoles.

RESULTS AND DISCUSSION

Chemical and Physical Characteristics of Atole Flours

Atole flours prepared by roasting, nixtamalization, and steeping had significantly different particle sizes. Raw and roasted grain flours had coarser particle size (smaller PSI) than nixtamalized and steeped flours. The smaller particle size of the wet-milled flours resulted because the grain was more finely ground and the coarse particles were removed by sieving.

Particle size of maize flours was significantly larger than sorghum flours, except for samples prepared by the steeping process (Table II). This resulted partially because the the small size of sorghum kernels was more amenable to milling than the large maize kernels.

Moisture of flours was generally lower for roasted flours (Table II). The pH of nixtamalized flours increased due to the use of alkali (CaO) during processing. The pH of steeped grain was significantly reduced during soaking due to activity of lactic bacteria. The pH of sorghum *atole* flours was slightly higher than for maize flours except when prepared by the steeping process. Possibly during drying, sorghum dehydrated more rapidly with less microbial fermentation and acid production.

Protein content of flour was affected by processing. Nixtamalization caused removal of soluble starch and pericarp from grain, which increased protein levels. Steeped grain flours contained less protein because soluble and suspended proteins were discarded during processing. Banigo and Muller (1972) reported protein losses from 5 to 15% during *ogi* preparation, i.e., wet milling of maize, sorghum, and millet.

Protein digestibilities of maize *atole* flours were slightly higher than for sorghum flours (Table II). Protein digestibility of roasted and nixtamalized *atole* flours was slightly lower than raw grain

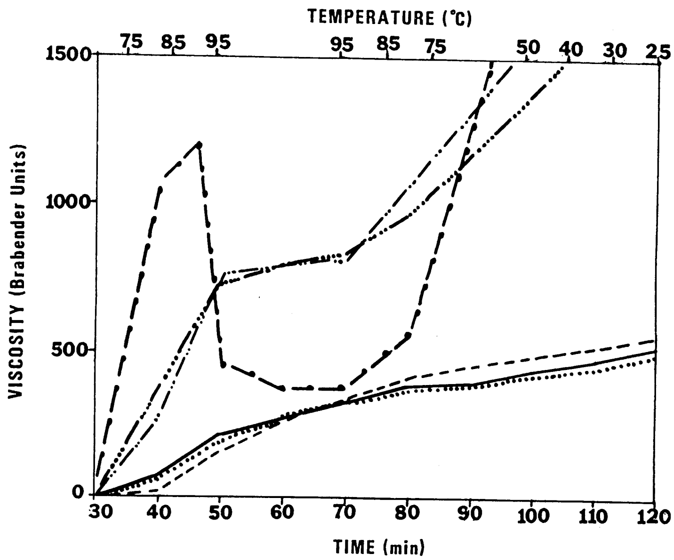

Fig. 3. Cooking properties of *atole* flours (12%, w/v) prepared from maize and decorticated sorghum using an amylograph. Legend: ---- raw maize, — — raw sorghum, ——— roasted maize, • • • • roasted sorghum, – – nixtamalized maize, and —•••— nixtamalized sorghum.

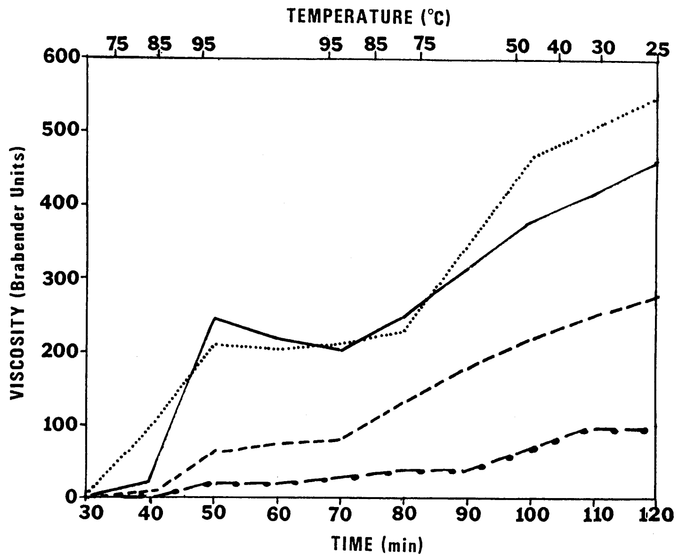

Fig. 4. Cooking properties of *atole* flour (6% w/v) prepared from maize and decorticated sorghum using an amylograph. Legend: — — raw maize, – – raw sorghum, • • • • steeped maize, and ——— steeped sorghum.

TABLE II
Physical and Chemical Properties of *Atole* Flours Prepared from Maize or Decorticated Sorghum[a]

Process/Grain	PSI[b]	Moisture (%)	pH	Protein[c] (%)	Protein Digestibility[d] (%)	Starch (%)	ESS[e] (mg/g)
Raw							
Maize	62	9.6	5.9	9.1	88.4	69	351
Sorghum	64	11.6	6.5	9.7	87.3	78	390
Roasted							
Maize	65	7.2	5.7	10.0	86.4	65	295
Sorghum	67	7.2	6.2	10.6	83.4	69	355
Nixtamalized							
Maize	70	7.5	7.1	10.2	86.7	70	745
Sorghum	76	8.5	8.6	10.6	83.6	74	757
Steeped							
Maize	100	9.5	3.8	7.1	88.2	75	245
Sorghum	100	9.7	3.5	8.2	85.0	79	238
LSD (0.05)	1.5	0.94	0.21	0.73	0.97	3	61

[a] Values from three observations of two replicates.
[b] Particle size index.
[c] Protein content expressed as ($N \times 6.25$) on a dry weight basis.
[d] Multienzyme (pH-stat) procedure.
[e] Enzyme-susceptible starch (mg glucose/g starch).

flours, particularly for sorghum. Axtell et al (1981) also observed that cooked sorghum proteins had lower digestibilities than uncooked sorghum proteins.

Starch contents of (decorticated) sorghum flours were higher than those of (whole) maize (Table II). This resulted because decortication of sorghum primarily removes nonstarch constituents. Roasted *atole* flours had decreased starch content, probably due to degradative reactions (pyrolysis) occurring during roasting. Steeping of maize increased its starch content because more protein was discarded with the water during processing.

Nixtamalization increased ESS values (Table II) because the process included an aqueous heat treatment, whereas dry roasting did not change ESS values.

Cooking characteristics of *atole* flours were determined using the visco-amylograph (Figs. 3 and 4). Roasting decreased amylograph viscosities of *atole* flours, apparently because the swelling potential of starch granules decreased, or the starch molecules were depolymerized by dextrinization, or both. Takahashi et al (1982) also reported changes in starch structure after dextrinization of cereals, i.e., there was no expansion or rupture of starch granules during aqueous heating. Amylograph viscosities of nixtamalized maize *atole* flour were slightly lower than those of nixtamalized sorghum *atole* flour. Steeped *atole* flours had increased amylograph viscosities (Fig. 4), because they had higher starch contents, smaller particle size, and lower starch damage than other processed or raw samples. Nixtamalized *atole* flours had cooking viscosities lower than for raw grain flours except during part of the hot holding and cooling stages of nixtamalized sorghum flour. Nixtamalized maize *atole* samples had amylograph curves similar to those of commercial dry tortilla flours (Bedolla and Rooney 1984).

Viscosity of *Atoles*

Atoles contained different solids levels to produce products with characteristics comparable to those traditionally consumed in Mexico (Fig. 5). The η_{app} of sorghum *atoles* was higher than *atoles* from maize. This resulted because sorghum *atole* flours contained more starch and had a smaller particle size than maize flours. Atoles from roasted flours (6.6% solids) had lower viscosities than *atoles* from nixtamalized or steeped flours (4.0 and 3.5% solids, respectively). Similar results were observed using the amylograph. Steeped *atole* flours produced more viscous *atoles* because of the flour's small particle size. *Atoles* from raw flours had low viscosities because the starch was entrapped in larger particles than the steeped *atole* flour.

Organoleptic Evaluation of *Atoles*

Most panelists who participated in the taste panel evaluations were familiar with *atole* because they consumed it regularly. The quality of good *atole* was described as having a slightly thick consistency, a smooth to slightly sandy texture, and a lightly roasted, lightly nixtamalized, or artificial flavor, depending upon processing conditions. Some panelists commented that roasted sorghum *atole* had a more intense and acceptable roasted flavor than roasted maize *atole*. The acceptability of nixtamalized *atoles* was also very good (Fig. 6). Atole from steeped sorghum was very bland, whereas steeped maize *atole* had a mild corn flavor. Atoles from roasted maize and steeped sorghum, however, were less acceptable than other atoles. The effect of processing was evaluated separately using sorghum *atoles* (Fig. 6). Atoles from roasted and nixtamalized sorghum were acceptable, whereas *atole* from steeped sorghum was less acceptable.

The preference test revealed that 77% of the panelists preferred *atole* from roasted sorghum over roasted maize *atole*, nixtamalized maize *atole* (58%) over nixtamalized sorghum *atole*, and steeped maize *atole* (84%) over steeped sorghum *atole*. Roasted (47%) or nixtamalized (42%) sorghum *atoles* were preferred over steeped sorghum *atole*. These data support the results obtained from the hedonic scale.

Maize, sorghum, and millet were steeped and fermented into good quality thin porridge, such as *ogi*, using traditional Nigerian processes (Banigo and Muller 1972). Akingbala et al (1981) also

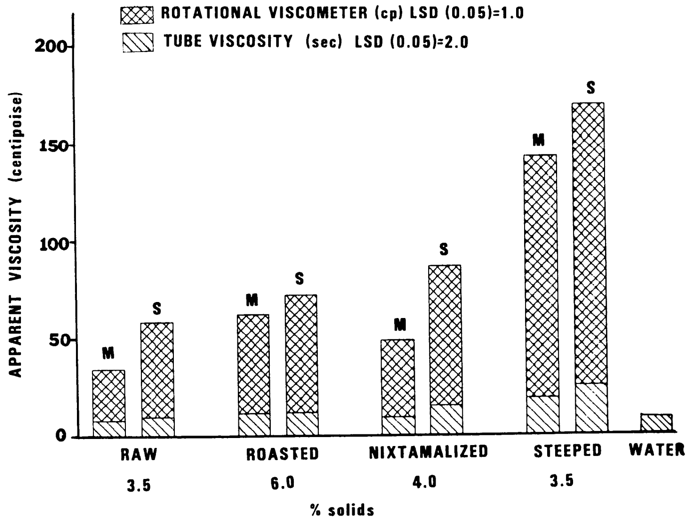

Fig. 5. Apparent viscosity of *atoles* prepared from maize and decorticated sorghum. Legend: **M** = maize, and **S** = sorghum.

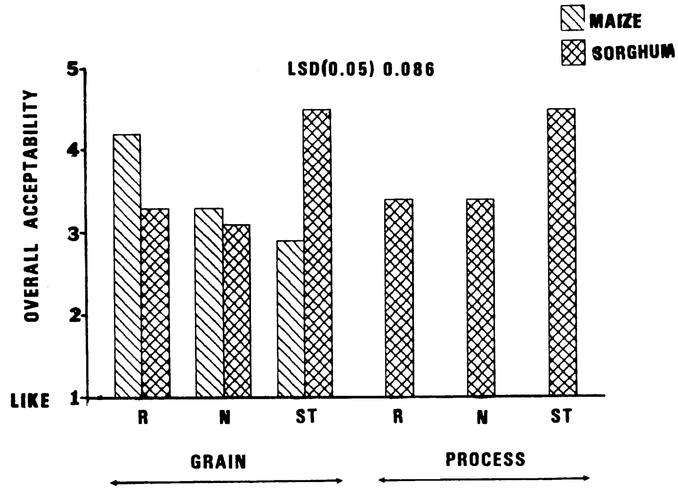

Fig. 6. Overall acceptability of *atoles* evaluated by Latin American panelists. Maize and decorticated sorghum were prepared into *atole* by roasting (**R**), nixtamalization (**N**), or steeping (**ST**).

prepared *ogi* by steeping and fermenting. They concluded that sorghums with a white pericarp and a normal ratio of amylose to amylopectin produced *ogi* with the highest ratings of color, taste, texture, aroma and consistency.

CONCLUSIONS

Sorghum with a white pericarp (CSH-6) was processed into several *atole* flours and *atoles* that had properties similar to maize products. Sorghum exhibited advantages over maize during processing into *atole* flours. Dehydration of nixtamalized sorghum was faster than that of maize, and the size of processed and dried sorghum kernels was more amenable to milling than for maize. Roasting of maize and sorghum decreased their ability to form viscous products apparently because starch was dextrinized. Roasted *atole* from maize and especially sorghum was acceptable. Nixtamalization generally improved cooking properties and yielded acceptable *atole* products. Steeping increased flour fineness, cooking viscosity, and yielded an *atole* with a very bland taste. Thus, *atoles* traditionally prepared from maize were successfully prepared from sorghum, a lower-cost food source.

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