Corn Tortillas: Evaluation of Corn Cooking Procedures

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ABSTRACT

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Corn was cooked by a traditional village method, a simulated commercial method, and a pressure-cook method. For each method, corn was undercooked, optimally cooked, and overcooked. Properties of cooked corn (*nixtamal*), *masa*, and tortillas were evaluated. *Nixtamal* was forced through a stainless steel cone and die shear cell, and the response was measured with the Instron Universal Testing Machine. Texture, color, and acceptability of tortillas made by the traditional methods were superior to those made from the commercial and pressure-cook methods. The pressure-cook method produced sticky *masa* and pale white, undesirable tortillas. Tortillas from the commercial method were least desirable, having grainy texture, dark color, and poor rollability. The traditional method produced the greatest loss of dry matter from the grain. The pressure-cook method produced a greater loss of dry matter than the commercial method. Amylograph peak viscosity, particle size of *masa*, and moisture content of *nixtamal* and *masa* were related to cooking method and time. Both *nixtamal* shear force and tortilla texture evaluated with the Instron were positively correlated. This indicated that the cone and die shear cell used with the Instron might be a potentially useful method of measuring completeness of cooking. The feasibility of developing such a method is discussed.

Traditionally, corn is cooked and steeped in alkali solution, washed to remove excess alkali, and ground on a stone mill into *masa*, which is pressed into flat, circular tortillas. Tortillas are cooked on a hot griddle. Rapid increases in tortilla consumption in the United States have introduced changes in tortilla processing. The traditional corn-cooking procedures (Cravioto et al 1945, Katz et al 1974) are being replaced by large-scale commercial operations in which corn is cooked and ground immediately with little or no steeping, and tortillas are cooked in large, automated cookers.

Commercial tortilla production demands optimum cooking of corn to produce *masa* of proper consistency and repeatable quality. Factors that may affect cooking of corn are kernel hardness, kernel structure, and age of the corn. A practical method to determine corn hardness is not available. Artificial corn-drying methods may affect kernel hardness test results.

Most published research on corn cooking quality has been done on cultivars with significantly different endosperm textures (Bazua et al 1978, Cortez and Wild-Altamirano 1972, Martinez-Herrera and Lachance 1979). In addition, variation among kernels within a corn sample is significant, so several measurements need to be made to differentiate among corn samples with similar characteristics.

Different methods of cooking corn to determine some of the chemical and physical changes that occur during the tortilla-making process are evaluated. In addition, the use of these properties to develop a method that could be used to measure completeness of cooking is discussed.

MATERIALS AND METHODS

Corn Samples

A commercial white dent corn hybrid grown at Uvalde, TX, in 1977 was used throughout the experiment.

Nixtamal Preparation

Three cooking methods, a traditional village method, a simulated commercial process, and a laboratory pressure-cook procedure, were used to prepare alkaline-cooked maize, referred to as *nixtamal*. Through preliminary experiments, optimum cooking time was determined subjectively for each method and was 75, 180, and 25 min for the traditional, commercial, and pressure-cook methods, respectively. For each method, 500 g of corn, 10 g of CaO, and 1 L of tap water were used.

For the traditional method, corn, lime, and water were boiled for 35 min on a conventional electric hot plate and then simmered for 40 min at 85°C in a stainless steel pot. Boiling temperature was reached in 8–10 min. The mixture was stirred occasionally with a rubber spatula. Different lots of corn were boiled for 75 min, 60 min, and 90 min for the optimally cooked, undercooked, and overcooked samples, respectively. The cooked mixture was covered with aluminum foil and steeped 15 hr at room temperature. Finally, the corn was washed thoroughly with tap water (final pH 8.0) and ground into *masa*.

For the commercial method, the mixture of corn, lime, and water was cooked in a stainless steel pot on a conventional electric hot plate. A thermocouple monitored the temperature, which was raised from 23 to 85°C at a rate of 0.66°C/min. After the mixture reached 85°C, the temperature was held constant and the mixture cooked for 109, 139, and 169 min for the undercooked, optimally cooked, and overcooked treatments, respectively. The nonsteeped *nixtamal* from each treatment was washed with tap water (final pH 8.0) and ground immediately.

The pressure-cook method involved placing the mixture of corn, lime, and water into a 1-qt canning jar. The jar was placed in a 21-qt Presto canner pressure-cooker, and the mixture was pressure-cooked at 1.06 kg/cm^2 for 25 min. The total cooking time was 55 min, including the 15 min required to reach the working pressure and the 15 min required to lower the pressure. Then, the *nixtamal* was immediately washed with tap water and ground into *masa*. The undercook time was 15 min (45 min total), and overcook time 35 min (65 min total).

Masa Production

All *nixtamals* were ground with a mechanical stone grinder (Curry Mfg. Co., San Antonio, TX). The same relative gap between the grinding stones was used for grinding all *nixtamals*. Finally, the *masa* was kneaded manually about 2–3 min to form a semisticky dough.

Tortilla Preparation

The *masa* was pressed into a tortilla 12.5 cm in diameter with a tortilla machine (Curry Mfg. Co.). Each tortilla was cooked at 350°C for 1 min on each side on a preheated stainless steel gas griddle. Then, the tortilla was turned over and pressed with a spatula for 15 sec to induce puffing. The tortillas were cooled for 2 min and stored in sealed plastic bags.

Nixtamal Shear Force

Nixtamal shear force was evaluated using the Instron (model TTD, Instron Corp., Canton, MA) with a cone and die shear cell (Fig. 1). The die was placed inside the barrel after the entrance cone. Next, 30 g of *nixtamal* was placed into the barrel. Complete extrusion of the *nixtamal* was made with a 9,090-kg$_f$ load cell. Instron settings were 127 mm/min and 125 mm/min for the crosshead and chart speeds, respectively. *Nixtamal* shear force was

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expressed as the average of three maximum peaks from the force displacement curve (Fig. 2a). The experiment was replicated three times for each cooking method and time.

Tortilla Texture

One tortilla was placed between two metal rings, each 10 cm in diameter. A stainless steel rod with a 1.6-cm diameter, positioned perpendicularly to the rings, was attached to the Instron. The Instron crosshead moved the rod downward at a rate of 112 mm/min until it punctured the tortilla. A 9.0-kg force load and a chart speed of 127 mm/min were used. Texture of the tortilla was expressed as the peak force required to stretch and finally break through the tortilla (Fig. 2b). The peak force was corrected for tortilla thickness:

$$\text{Corrected peak force} = \frac{\text{Peak force reading}}{\text{Thickness of tortilla}} \text{(in kg force)}$$

Color Measurements

L, a, and b values were recorded with a Hunter lab color difference meter for *nixtamal*, *masa*, and tortilla made from each treatment. A standard yellow tile was used to calibrate the colorimeter (L = 78.2, a = 2.3, b = 22.4).

Particle Size Determination

A *masa* slurry (50 g of *masa* in 100 ml of H_2O) was prepared from the undercooked, optimally cooked, and overcooked treatments. The slurry was passed through a series of sieves (12-, 20-, 30-, 40-, and 100-mesh) assembled on an Eberbach reciprocating shaker. Then, the slurry was washed with tap water, and the overs from each screen were quantitated. The weights of overs dried 12 hr at 60°C were substituted in the following formula to calculate the particle size index (PSI):

$$\text{PSI} = \left(\frac{\text{wt of sieve \#12 overs}}{\text{total wt recovered}} \times 1.2\right) + \left(\frac{\text{wt of sieve \#20 overs}}{\text{total wt recovered}} \times 2.0\right) + \left(\frac{\text{wt of sieve \#30 overs}}{\text{total wt recovered}} \times 3.0\right) + \left(\frac{\text{wt of sieve \#40 overs}}{\text{total wt recovered}} \times 4.0\right) + \left(\frac{\text{wt of sieve \#100 overs}}{\text{total wt recovered}} \times 10\right)$$

Measurement of Dry Matter Loss During Cooking of Corn

The steeping water and the wash water were combined, thoroughly homogenized, and 10.0-ml aliquots were evaporated to dryness. The dry weight was used to calculate the total dry matter lost during cooking, steeping, and washing procedures.

Starch Analyses

Dried (9% moisture), ground *nixtamal* and *masa* samples (0.20 g) were mixed with 20 ml of distilled water and autoclaved (1.4 kg/cm^2) for 2 hr. The samples were then incubated for 30 min with buffered glucoamylase (Diazyme L100) until completely hydrolyzed. Total glucose was determined on the Technicon Autoanalyzer using the bound hexokinase method (Technicon method SF4-0046 FA8, 1978). Two observations were made for each *nixtamal* sample. Starch content was calculated by multiplying the percent glucose by 0.90.

Enzyme-Susceptible Starch (ESS)

The extent of starch gelatinization was measured by determining the amount of glucose released by enzymatic hydrolysis of the starch in the *nixtamal* and *masa*. Samples (~0.25 g) were treated in a manner similar to that for total starch, but without autoclaving. The enzyme-substrate mixture was incubated at 60°C for 30 min. The enzyme was inactivated by addition of 3 ml of a mixture of H_2SO_4 and water (1:9) followed by 2 ml of 12% sodium tungstate.

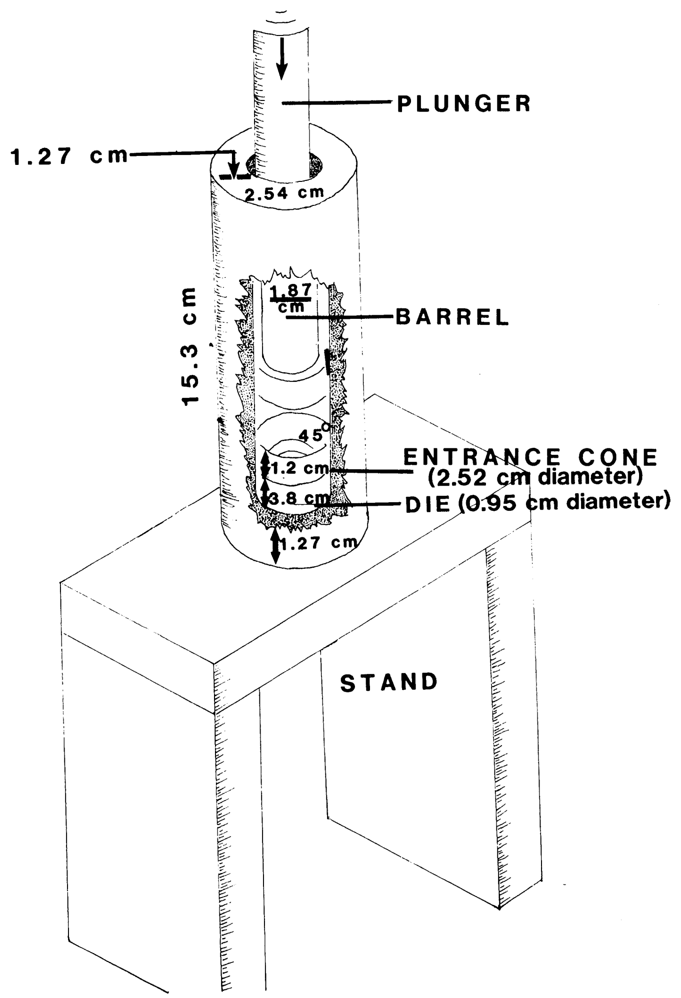

Fig. 1. Cone and die shear cell used to measure *nixtamal* shear force.

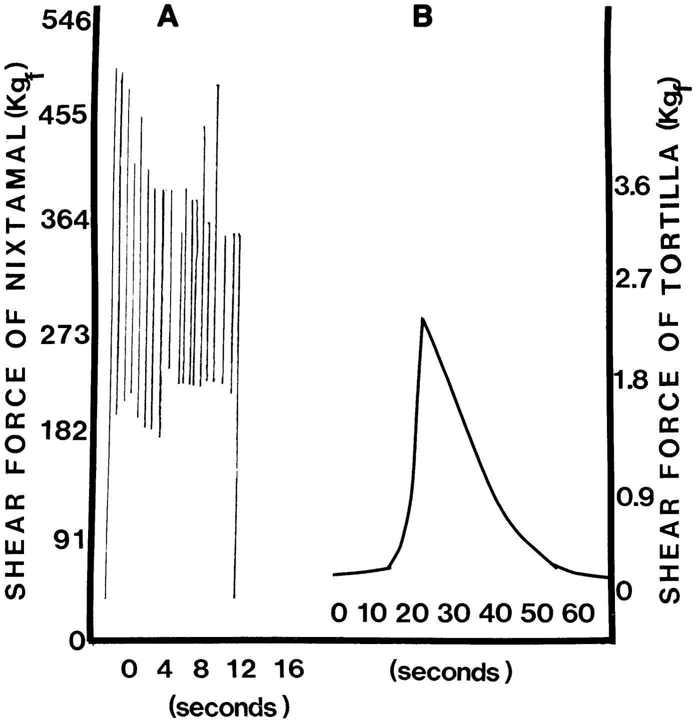

Fig. 2. A, A typical Instron force-displacement curve for *nixtamal* forced through the cone and die shear cell. **B,** tortilla texture.

The ESS was expressed as glucose released (Technicon method SF4-0046 FA8) divided by total of *nixtamal* sample weight.

Viscosity of *Masa*

Pasting properties of the *masa* were evaluated with a Brabender Visco Amylograph. Suspensions were made by mixing 18 g of the wet sample with 42 ml of distilled water. The mixture was stirred with a glass rod until homogeneous and poured into the small amylograph bowl. The initial temperature of the amylograph was set at 25°C, and the temperature was allowed to increase 1.5°C/min until the temperature reached 95°C. The sample was cooked at 95°C for 15 min, and the peak viscosity was recorded.

Statistical Design

All nine treatments, including three cooking times for each of the three cooking methods, were made in one day, and the experiment was replicated on each of three different days, with two observations per day. A 3 × 3 × 3 factorial design was used, and the data for the chemical and physical properties of the *nixtamal*, *masa*, and tortilla were analyzed statistically with an analysis of variance. The means were separated by Duncan's multiple range test. Correlation coefficients were calculated between the physical and chemical properties of the *nixtamal*, *masa*, and tortillas.

RESULTS AND DISCUSSION

Dry Matter Losses

The traditional method produced the greatest loss of dry matter during processing, and the commercial method produced the smallest loss (Fig. 3). The commercial method lost significantly less dry matter than the pressure-cook method. Within each cooking method, the dry matter loss increased as cooking time increased. These data compare favorably with information by Katz et al (1974), who reported a 5–14% loss of dry matter during conversion of raw corn into *nixtamal* by traditional village methods. Bressani et al (1958) reported that 11–12% of dry matter was lost during cooking, steeping, and washing procedures, which compares favorably with traditional dry matter losses. Information on losses during commercial cooking of corn is not available, but unpublished information suggests that they are high and significant in both pollution and economics. The extended steeping time of traditional cooking procedures accounts for the additional losses of dry matter and is another reason that commercial processes have eliminated or reduced steeping. Thus, the extra expense of sewage treatment and outright loss of material is reduced. The major dry matter losses during cooking are the pericarp, solubles from the germ, and solubilization of proteins. For example, protein was 35, 24, and 28% of the total dry matter lost during cooking with the traditional, pressure-cook, and commercial methods, respectively.

Nixtamal Shear Force

The shear force was significantly affected by cooking methods and time within each method (Fig. 4). The greatest force (harder *nixtamal* texture) for optimally cooked corn was required for the commercial *nixtamal*, whereas the least was required for the traditional *nixtamal*. For each cooking method, the shear force decreased as cooking time increased. Because cooking time for each method was optimized to produce *nixtamal* that made *masa* with good rheological properties, we had hoped that the shear force for optimally cooked *nixtamal* would be the same for each method. However, the large differences reflected different modes of cooking. The traditional method produced the softest kernels because sufficient time elapsed to permit more complete hydration of the kernel. For the other methods, the inside of the kernel was not cooked or even thoroughly hydrated. Thus, the shear force was higher because of the harder, drier centers of the kernels. *Masa* could be made from the optimally cooked treatment for each process because *masa* is a mixture of gelatinized and ungelatinized starch granules obtained by the combination of cooking and grinding. Grinding distributes the gelatinized starch paste around the broken, partially hydrated endosperm cells of the center of the corn kernel. This combination of cooking and mechanical action produced the dough. Thus, the undercooked *nixtamal* did not have sufficient gelatinized starch granules to permit proper *masa* structure. By contrast, too many starch granules were gelatinized in the overcooked *nixtamals*, which produced *masa* that was too sticky to be handled in the equipment. This was true for the overcooked *nixtamals* of all three methods.

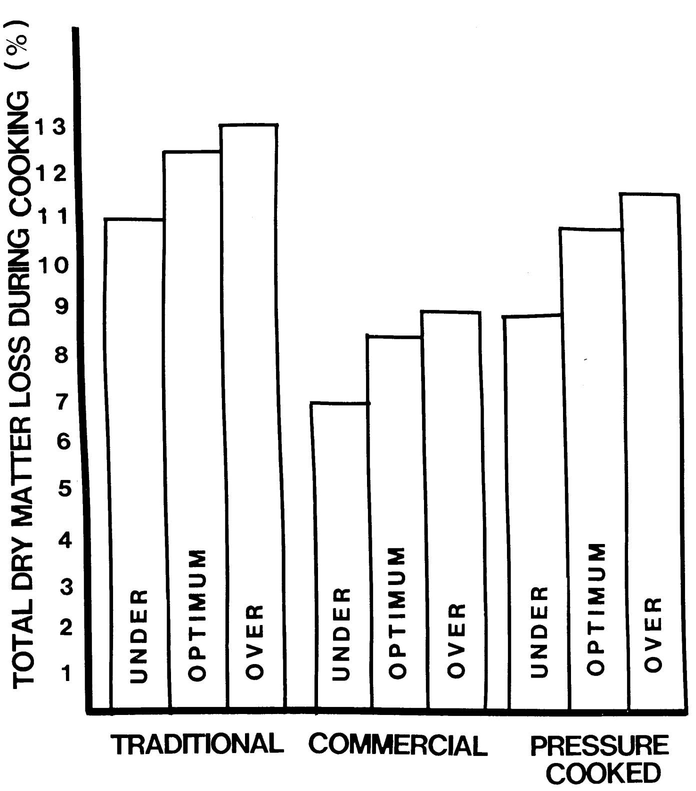

Fig. 3. Total dry matter losses during cooking and washing of *nixtamal* produced by three methods of cooking.

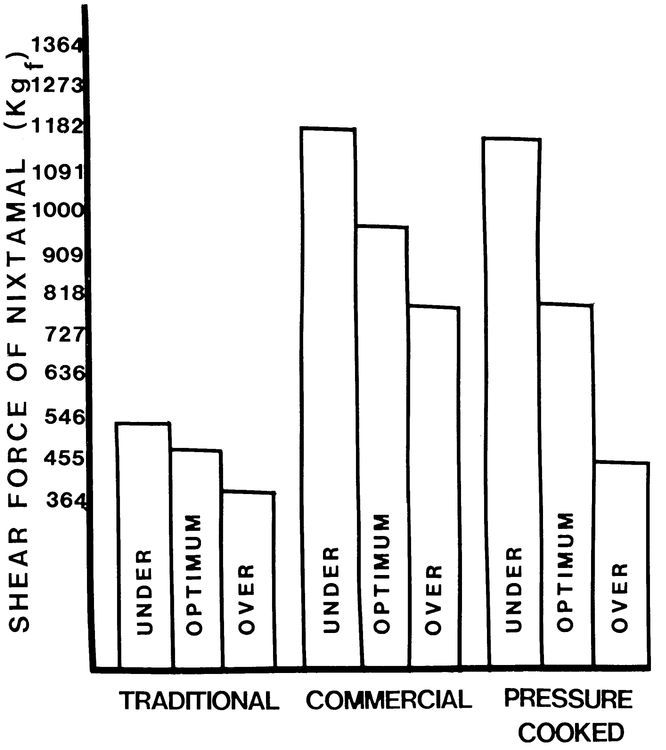

Fig. 4. The force measured with an Instron required to shear *nixtamal* through a cone and die shear cell.

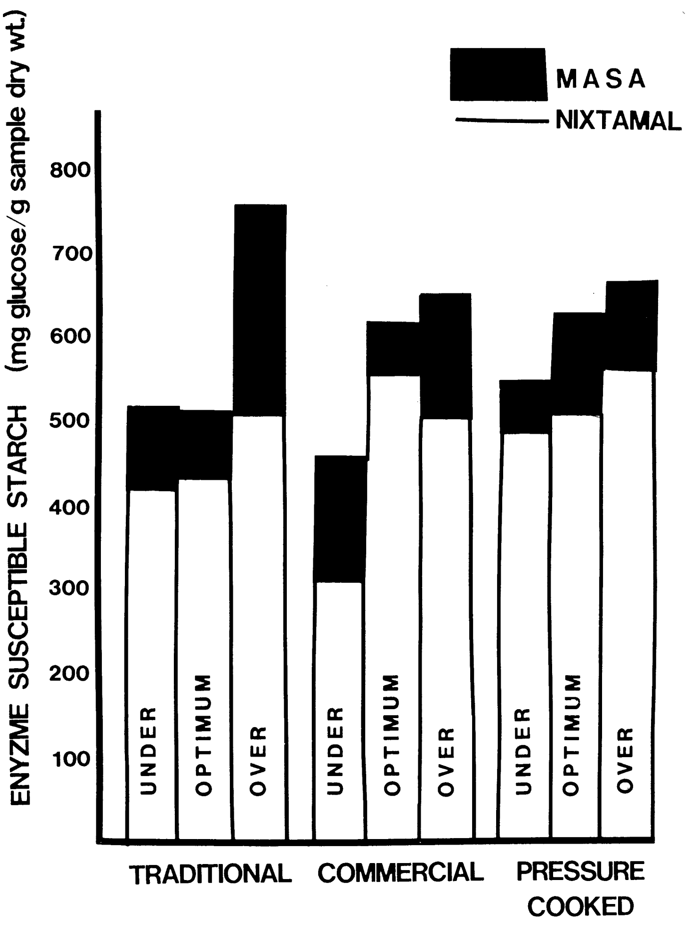

Fig. 5. Enzyme-susceptible starch content of *nixtamal* and *masa*.

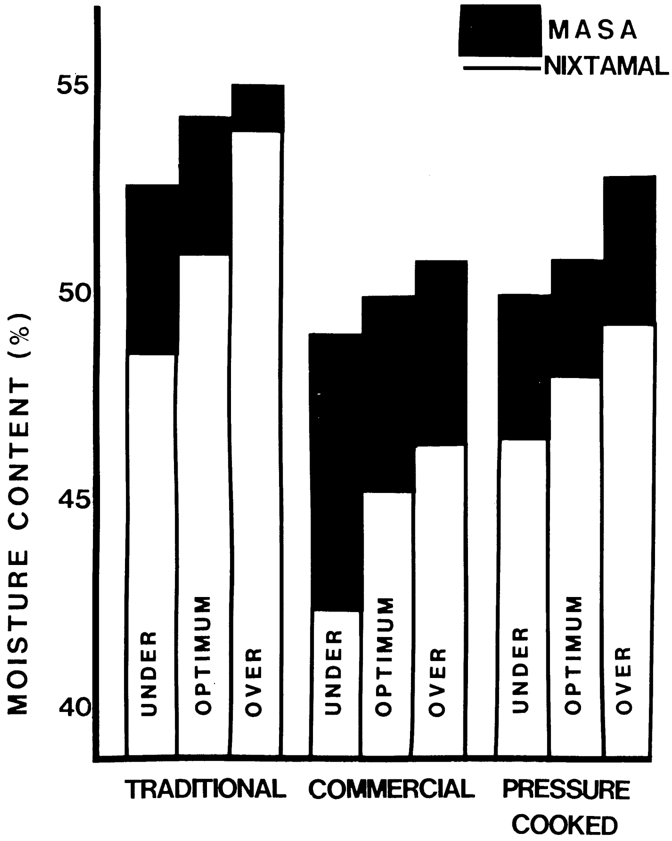

Fig. 6. Moisture content of *nixtamal* and *masa*.

Starch Gelatinization and Tortilla Processing

The moisture content and ESS values for *nixtamal* and *masa* are shown in Figs. 5 and 6. The ESS is an index of the relative amount of starch gelatinization. The amylograph peak viscosity value for *masa*, another index of gelatinization, is shown in Fig. 7. Moisture content, ESS, and amylograph viscosity values were significantly different among the cooking methods and among cooking times within a specific method. The ESS indicates that grinding the *nixtamal* into *masa* increased the extent of starch gelatinization. However, ESS did not provide logical values. For instance, ESS values of undercooked and optimally cooked traditional *nixtamal* and *masa* were the same. In addition, the ESS values for the pressure and commercial methods were not significantly different. Thus, the ESS test is variable, with insufficient sensitivity to detect differences among *nixtamals* and *masas* with considerably different characteristics.

The amylograph peak viscosity was expected to decrease with increased gelatinization of starch in the corn. The data fit the expected results for all three cooking procedures. The viscosity was highest for the commercial method, followed by the traditional and the pressure-cook methods. Within each method of cooking, a linear decrease in viscosity occurred (Fig. 7).

Particle Size and *Masa* Properties

Figure 8 shows the PSI of the *masa*. The pressure-cooked *masa* had the finest particle, and the commercially cooked *masa* had the largest particles. The traditionally cooked *masa* had intermediate particle size. The pressure-cooked *masa* was difficult to press into tortillas because it was sticky even for the undercooked and optimally cooked samples. In contrast, *masa* from the commercial method was coarse and crumbly, which affected tortilla texture. PSI measurement is tedious and subject to considerable errors; however, it does appear to be potentially useful in characterizing *nixtamal* and in indirectly characterizing tortilla quality. An improved PSI method would facilitate faster acquisition of accurate PSI data.

Potential Methods to Predict Cooking Time of Corn

Nixtamal shear force (NSF) and moisture content and the PSI of *masa* appear to have potential for characterizing the extent of cooking that occurs when corn is cooked in alkali. The NSF was closely related to cooking time, *nixtamal* moisture content (r =

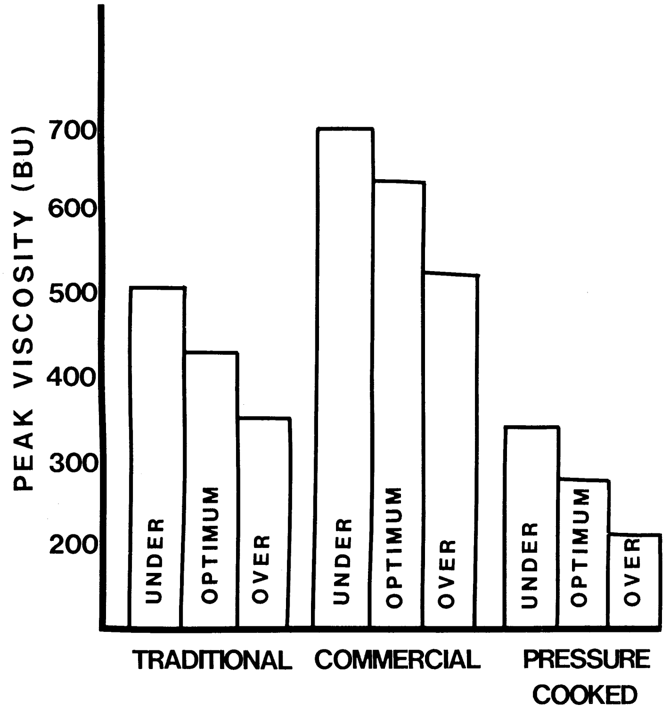

Fig. 7. Amylograph peak viscosity for *masa*.

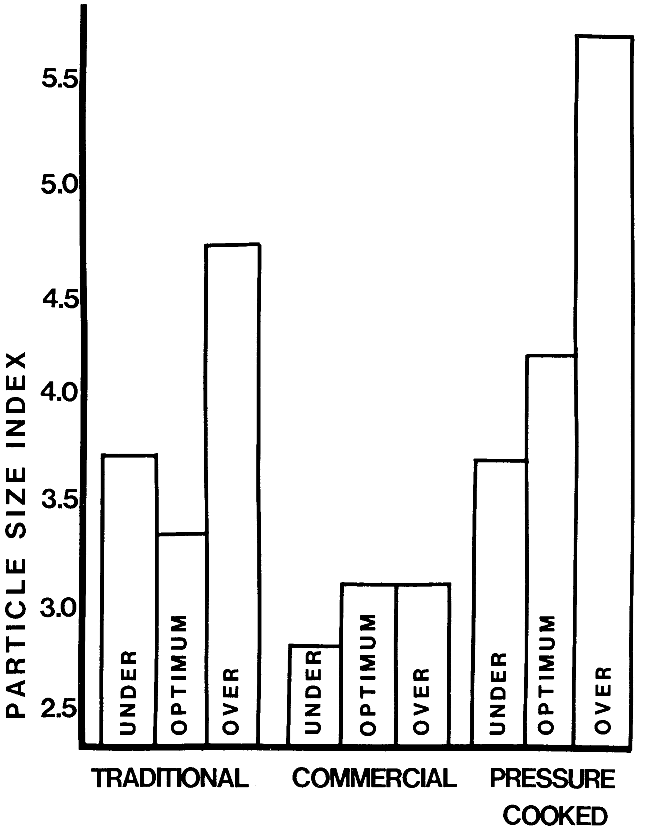

Fig. 8. Particle size index of *masas*. A large particle size index indicates a higher proportion of small particles.

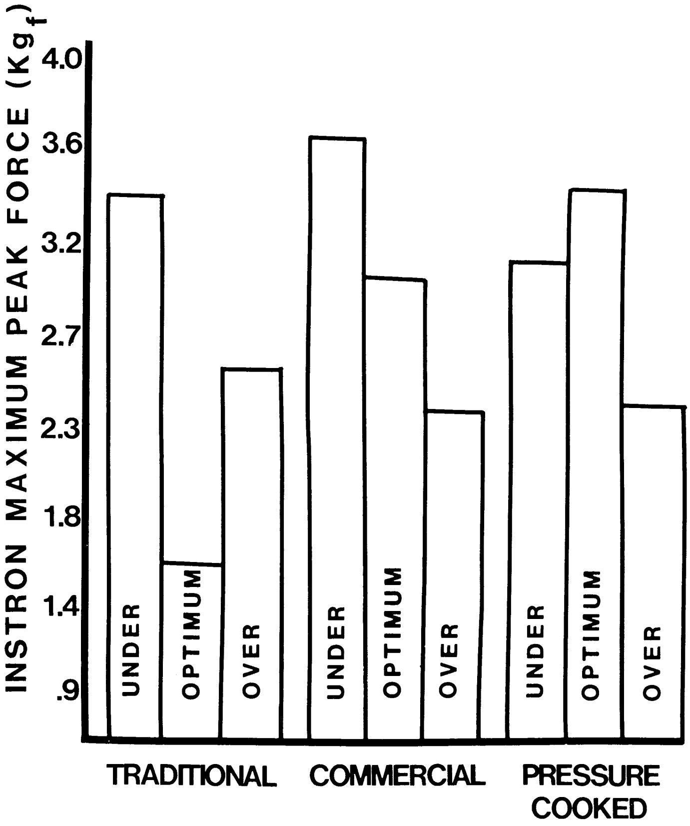

Fig. 9. Texture of tortillas measured with a plunger-tension test on the Instron Universal Testing Machine.

0.86, df = 25), *masa* particle size (r = 0.58, df = 25), and *masa* moisture content (r = 0.87, df = 25). The NSF might be the most useful practical index for predicting corn cooking time. The relationship between actual cooking time in the commercial plant and the NSF of *nixtamal* cooked from a given lot of corn using different cooking times in a standardized lab cooking test could be developed. This relationship could then be used to predict the optimum cooking time of corn samples with unknown cooking times. The NSF method is practical for laboratories with access to an Instron. Other methods of measuring NSF could be devised if this relationship proves to be feasible.

The enzyme-susceptible starch method was not a useful method for characterizing the extent of cooking the *nixtamal*, nor was it a useful indicator of *masa* properties. For example, *nixtamal* ESS was not significantly correlated with NSF (r = 0.16, df = 25) or *nixtamal* moisture content (r = 0.23, df = 25). A good practical method of moisture determination in *nixtamal* might be a possible alternative to NSF measurements. Further work on NSF and moisture content of *nixtamal* should be done.

Tortilla Quality Related to Cooking Methods

Tortillas made from the traditional method at optimum conditions were significantly softer than those made with the other methods (Fig. 9). Instron texture readings, subjective tests of rollability, puffability, and acceptability all indicated that the most acceptable tortillas were made by the traditional method. All three cooking methods had significant daily variation in tortilla texture (Johnson et al 1980). We measured tortilla texture with more accurate, reproducible methods. However, tortillas made from overcooked *nixtamal* clearly had rubbery, undesirable texture. The tortillas from undercooked *nixtamal* were more crumbly than those from optimally cooked *nixtamal*.

Moisture content of *masa* significantly affected the physical properties of the tortilla. Tortilla texture (expressed either as total area under the force displacement curve or as peak height) was significantly related to *masa* moisture content. Increased moisture in the *masa* produced tortillas with softer texture. *Masa* produced by the traditional method had a significantly higher moisture content than *masa* obtained from the pressure and commercial methods because of the long steep time used during traditional processing of the corn, which facilitated grinding of the *nixtamal* and handling of the *masa*. The color of tortillas made from the traditional method was golden yellow compared to the darker color of pressure-cooked tortillas and pale white of the commercial tortilla (Table I). Overall, the texture, color, and acceptability of tortillas made from the traditional method were superior to those made with other methods. The pressure method produced sticky, overgelatinized *masa* that was difficult for the equipment to handle. Tortillas made from the commercial method were least desirable and had grainy texture and poor rollability because of the lack of uniform cooking, which could be improved either by constant stirring of the corn-lime mixture or by periodic injection of steam.

TABLE I
Mean Color Readings[a] for Tortillas Made with Three Cooking Methods[b]

	Nixtamal			*Masa*			Tortilla		
Method	L	a	b	L	a	b	L	a	b
Traditional	50.9 a	1.1	20.6 c	61.7 b	0.4	20.2 c	62.1 b	0.3	22.0 b
Commercial	53.4 b	−0.8	16.1 b	69.8 c	−0.7	15.0 b	61.6 b	−0.2	17.6 a
Pressure cook	53.8 c	0.4	15.6 a	58.0 a	0.5	14.0 a	59.4 a	0.8	16.6 a

[a] Hunter lab color differences meter readings.

[b] Within each column, values followed by different letters are significantly different ($P = 0.95$) by Duncan's multiple range test.

LITERATURE CITED

BAZUA, C. D., PEDROZA, R., GUERRA, R., and RODRIGUEZ, A. 1978. *Opaque-2* corn tortillas: Processing conditions for the traditional alkaline cooking method. Abstract B2-B. Sixth Int. Cereal and Bread Congress, Winnipeg, Manitoba, Canada.

BRESSANI, R., PAZ y PAZ, R., and SCRIMSHAW, N. S. 1958. Corn nutrient losses. Chemical changes in corn during preparation of tortillas. J. Agric. Food Chem. 6:770.

CORTEZ, A., and WILD-ALTAMIRANO, C. 1972. Mejoramiento nutricional del maiz Publication, L-3. I.N.C.A.P. Guatemala.

CRAVIOTO, R. O., ANDERSON, R. K., LOCKHART, E. E., MIRANDA, F. de P., and HARRIS, R. S. 1945. Nutritive value of the Mexican tortilla. Science 102:91.

JOHNSON, B. A., ROONEY, L. W., and KHAN, M. N. 1980. Tortilla-making characteristics of micronized sorghum and corn flours. J. Food Sci. 45:671.

KATZ, S. H., HEDIGER, M. L., and VALLEROY, L. A. 1974. Traditional maize processing techniques in the New World. Science 184:765.

MARTINEZ-HERRERA, M. L., and LACHANCE, P. A. 1979. Corn (*Zea mays*) kernel hardness as an index of the alkaline cooking time for tortilla preparation. J. Food Sci. 44:377.

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