Physico-Chemical Properties of Alkali-Cooked Corn Using Traditional and Presoaking Procedures

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ABSTRACT

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Compared to the traditional alkali cooking for corn, a 40% reduction in cooking time was achieved by presoaking before alkali cooking. Presoaking of white and yellow dent corn for 12 hr allowed imbibition of 45% of water and a 40-fold increase in calcium content. When presoaked or raw corn was cooked, dry matter losses, water uptake, calcium content, and enzyme-susceptible starch increased whereas amylograph maximum viscosity decreased. However, the decrease or increase in these parameters was faster in the presoaked corn samples than in the traditionally cooked corn. Scanning electron microscopy showed rapid changes occurring in the starch granules of the presoaked sample. For tortilla preparation, cooking 50 min after presoaking was required to optimally cook white or yellow corn compared to 80 min for the traditional alkali-cooking method.

Alkali cooking of corn is traditionally used for tortillas and most corn-based snack preparation. This procedure involves cooking corn in an alkaline solution (usually calcium hydroxide), steeping the cooked corn for 12–18 hr, and thorough washing. The cooked and washed corn is called *nixtamal*. The *nixtamal* is ground into masa, which is formed into the final product (Choto et al 1985). A positive relationship exists between the time required to cook the corn and the gelatinization of its starch (DesRosiers 1979, Khan et al 1982, Bedolla 1980). According to Sollano and Berriozabal (1955), a properly cooked corn is obtained when the moisture content of the *nixtamal* reaches 46%. Bedolla and Rooney (1982) indicated that the maximum amylograph peak viscosity of corn masa is indicative of the extent of cooking and starch gelatinization. Overcooking of corn is caused by high temperatures, high alkaline concentration, longer steeping times during the process of tortilla preparation, or a combination of these factors and produces lower viscoamylograph peak viscosities (Bedolla and Rooney 1982), indicating a high degree of starch gelatinization. Bedolla (1980) reported a direct relationship between the amount of enzyme-susceptible starch in the grain and the cooking time for different corn hybrids. Alkali cooking also increases the amount of calcium in the tortillas, because calcium hydroxide is the usual alkali used to raise pH. Calcium absorption from tortillas by rats was reported to be equivalent to that absorbed from milk (Bressani 1972). The increase in calcium content has been one of the major nutritional benefits of the alkali cooking process (Bressani et al 1958).

Soaking softens the seed coat of dry beans, thus reducing cooking time by allowing better water imbibition (Greenwood 1936, Master 1918, Perry et al 1976, Snyder 1936). Presoaking soybeans in an alkaline solution of sodium hydroxide increases the availability of niacin (Badenhop and Hackler 1970), thus presoaking has been recommended in order to facilitate cooking (Hoff and Nelson 1966). Practically, reductions in cooking time may be affected by the choice of soaking regimen (Rockland and Metzler 1967, Ankra and Dovlo 1978).

The purpose of this study was to evaluate the traditional alkali-cooking procedure and a procedure utilizing presoaking before alkaline cooking to determine differences in cooking times and chemical and physical properties of two commercial white and yellow dent corns.

MATERIALS AND METHODS

A commercial white dent (Asgrow 405W) and a yellow dent corn

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hybrid (Asgrow 404), grown in Uvalde, TX, in 1982, were used. All corn samples were free of cracked kernels and had no significant mold, staining, or insect damage. The corn samples were stored at −4° C until used.

Traditional Alkali Cooking

One kilogram of corn, 3 L of distilled water, and 10 g of lime were mixed in a stainless steel container. The mixture was heated to boiling (30 min) and then cooked for an additional 100 min with occasional stirring. Samples were collected at the boiling point and at 10-min intervals for chemical and physical tests during cooking.

Presoaking and Cooking

One kilogram of corn, 3 L of distilled water, and 10 g of lime were mixed in a stainless steel container. The mixture was allowed to steep at 25° C for 12 hr, heated to boiling (30 min), and then cooked for an additional 80 min with occassional stirring. Samples for chemical and physical tests were collected after soaking 12 hr, at the boiling point, and at 10-min intervals during cooking.

Water Uptake and Dry Matter Losses

Approximately 10 g of corn was weighed in aluminum tea balls. The tea balls were placed in the container along with the same corn, lime, and water mixture and cooked according to the prescribed treatment. For the traditional cooking procedure, one tea ball was removed when the boiling point was reached, and one was then removed every 10 min during cooking. For the presoaking procedure, corn samples in the tea balls were collected after the 12 hr steeping, once the boiling point was reached and at 10 min intervals during cooking. After it was removed from the container, each corn sample was drained, washed, and weighed. Water uptake was calculated on a dry matter basis.

% Water uptake =
100 × (cooked corn wt.) − (raw corn wt.) / (raw corn wt.)

Each sample of corn collected from the tea ball was used to measure water uptake. The samples were dried in a forced air oven at 100° C for 24 hr and weighed. Dry matter losses (DML) were calculated on a dry matter basis using the following equation:

% DML =
100 × (raw corn wt.) − (cooked corn wt.) / (raw corn wt.)

Calcium content was determined by neutron activation analysis. neutron flux of 2×10^{12}n Cm^{-2} s^{-1} in a Triga Mark I reactor (Nuclear Engineering Teaching Lab, the University of Texas at Austin). Gamma-rays emitted from ^{49}Ca (E_{γ} = 3.084 MeV) were counted for 10 min using a high-purity germanium detector (EG&G ORTEC).

Enzyme-susceptible starch was determined by glucoamylase hydrolysis of samples followed by glucose determination (Technicon method SFA-0046 FA8, 1978).

Amylograph maximum viscosity was measured using a Brabender viscoamylograph. Dried samples (40° C for 24 hr) of raw, presoaked, and cooked corn were milled to pass through a 1-mm screen using a Udy grinder. A 9% flour slurry (44.1 g flour [dwb] and 490 ml distilled water) was used for the amylograph test.

Scanning Electron Microscopy

Frozen corn kernels were critical-point dried, cut in half, and coated with gold/palladium. Specimens were viewed at 15 kV with a Joel JSM25S scanning electron microscope.

Tortilla Preparation

The traditional cooking and presoaking alkaline cooking procedures were used to prepare corn tortillas. The total processing time for both procedures was 15 hr. In the traditional method, a mixture of corn, lime, and water was heated to boiling (30 min) then cooked to optimum. The mixture was steeped for 15 hr, washed, and the *nixtamal* was stone ground into masa. For the presoaking method, the corn, lime, and water mixture was presoaked for 12 hr, heated to boiling (30 min), then cooked to optimum. The cooked corn was allowed to cool for 3 hr, washed, and the *nixtamal* was ground into masa. The masa from both procedures was shaped into tortillas and baked on a griddle as described by Choto et al (1985). The optimum cooking time was subjectively determined to be 80 min for the traditional method and 50 min for the presoaking procedure, based upon the ease of pericarp removal, absence of chalky endosperm, low amylograph maximum viscosity, and acceptable quality of tortillas. In the corn industry, determining optimum cooking time is still based on subjective evaluation by expert personnel. The optimum cooking time in the laboratory procedures was much longer than would be required in industry because a small 4-in. diameter stone was used.

RESULTS AND DISCUSSION

Water Uptake and Dry Matter Losses

Water uptake and dry matter losses occurring during alkali cooking of all samples are presented in Figures 1 and 2. Water absorption as a function of time was rapid during the first 30 min of cooking for both traditional and steeping procedures. The presoaked yellow and white corns contained around 47.07 and 48.09% water, respectively, after 12 hr of steeping before any heat treatment. In both procedures, the corn continued to absorb water during cooking. The total water uptake, at any given time, was higher for the presoaked corn. The 12 hr soaking before cooking allowed relatively high water absorption by corn kernels. To reach similar levels by the traditional method, the corn had to be heated first for 30 min to reach boiling, then cooked for an additional 10 min (a total of 40 min heat treatment in the traditional method versus no heat treatment in the presoaking method).

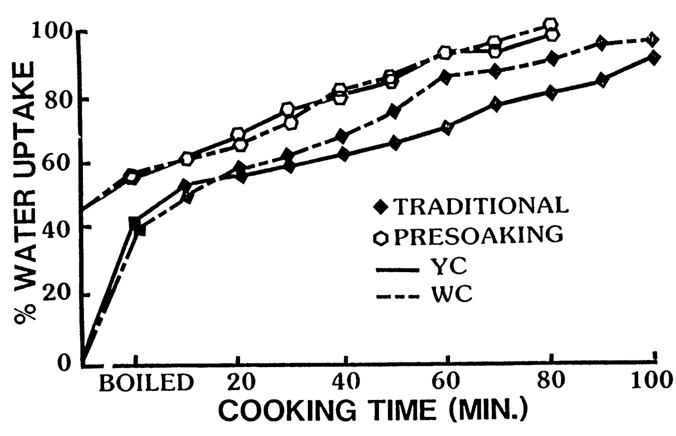

Fig. 1. Water uptake (%) during cooking of white (**WC**) and yellow corn (**YC**). (C.V. ranged from 0.88 to 2.09.)

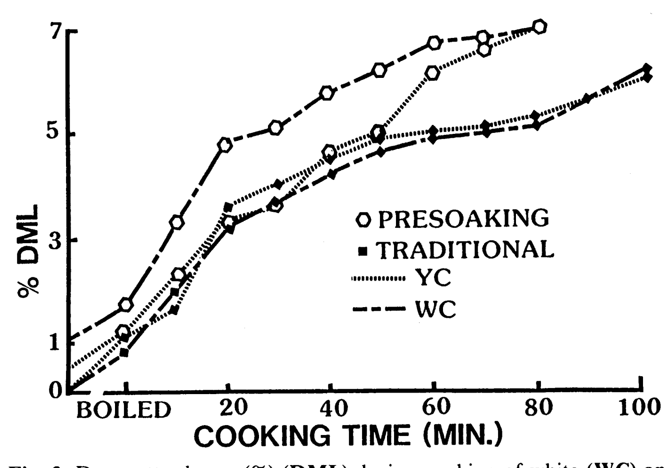

Fig. 2. Dry matter losses (%) (**DML**) during cooking of white (**WC**) and yellow (**YC**) corn. (C.V. ranged from 1.88 to 4.50.)

A similar phenomenon was observed for dry matter loss (Fig. 2). After the 12 hr presoaking in alkali, corn kernels had high dry matter losses compared to the traditional method. The dry matter losses continued to increase with increasing cooking time in both procedures, with higher values reached by the presoaked corn. The presoaking time (12 hr) before cooking allowed some of the soluble materials (protein, carbohydrates, etc.) to be lost to water during steeping and cooking. However, water uptake and total loss in dry matter when both corns were cooked to optimum for tortilla preparation (80 min in traditional procedure; 50 min in presoaking procedure) appeared to be similar except for presoaked white corn, which had a slightly higher dry matter loss.

Calcium Uptake

Lime is the major source of alkali currently used for processing of corn for human consumption. It is known that lime treatment improves nutritive value of corn by increasing calcium levels in the masa (Trejo-Gonzalez et al 1982). The absorption of calcium by corn kernels followed a pattern similar to water uptake (Fig. 3). Presoaked corn contained more calcium after 12 hr of steeping compared to 80 min of cooking in the traditional method. Figure 3 indicates that calcium content continued to increase with increasing cooking time for both procedures; however, the values were higher at any given time for the presoaking method as compared to the traditional method. Calcium content reached its maximum in the tortillas. The values for calcium in tortillas for the traditional method were 12,200 $\mu g/g$ and 9,250 $\mu g/g$ for white and yellow corn, respectively. However, for tortillas made after presoaking, the values for white and yellow corn were 11,170 $\mu g/g$ and 10,900 $\mu g/g$, respectively. In the presoaking procedure, the calcium was allowed to be absorbed by the corn for an additional 3 hr after the corn was cooked to optimum (50 min), whereas in traditional cooking, calcium continued to increase during the 15-hr steeping after cooking corn to optimum (80 min). Lime contributes to much of the flavor of products made from alkali-cooked corn. Calcium content in tortillas made with both procedures was similar and was within the range of other reported values for commercial tortillas; however, using the presoaking method the corn was cooked optimally in 60% of the time required by the traditional method.

Enzyme-Susceptible Starch

Higher values for enzyme-susceptible starch resulted as cooking time was increased (Fig. 4). As the cooking in alkali solution increased, more of the starch became susceptible to enzyme attack, because the alkali and higher temperatures aided the starch swelling process. Higher enzyme-susceptible starch was also obtained with the presoaking method than with the traditional alkali procedure. This can be explained by higher initial water and calcium uptake in the steeped method compared to the traditional method. Mechanical action during processing of the *nixtamal* into masa and the effect of cooking masa into tortillas produced more damage to the starch, which became more susceptible to enzyme attack. Table I shows enzyme-susceptible starch for dry grain, cooked grain, *nixtamal*, masa, and tortillas made from white and yellow corn cooked to optimum. At optimum cooking, corn kernels for both procedures contained similar amounts of enzyme-susceptible starches, with the exception of the white corn, which had a slightly lower value. The data indicated that tortillas contained the highest degree of enzyme-susceptible starch compared to cooked corn, *nixtamal*, and masa. This is caused by the mechanical action and heat treatment applied during the conversion of *nixtamal* into tortilla. Tortillas made from the presoaked corn were slightly higher in enzyme-susceptible starch. The presoaking may accelerate starch gelatinization and rupture. This did not cause any significant problem while processing the presoaked, cooked corn into tortillas.

TABLE I
Enzyme-Susceptible Starch (%) for White and Yellow Corn and Their *Nixtamal*, Masa, and Tortillas[a]

	Traditional Method		Steeping Before Cooking	
	White Corn	Yellow Corn	White Corn	Yellow Corn
Dry grain	16.9 d[b]	16.8 d	16.9 d	16.8 d
Nixtamal	37.7 c	34.1 c	39.4 c	39.0 c
Masa	49.3 b	45.1 b	54.7 b	55.9 b
Tortillas	59.3 a	57.7 a	59.3 a	57.7 a
C.V.	7.29	4.93	3.97	2.69

[a] Nixtamal, masa, and tortillas were prepared from corn cooked for 80 min using the traditional method or 50 min using the presoaking method.
[b] Means in a column with the same letters are not significantly different at the 0.01 level.

Amylograph Maximum Viscosity

An increase in water and calcium absorption caused by steeping and cooking resulted in a greater degree of starch gelatinization in the corn kernel. The amylograph maximum viscosity decreased as cooking time increased for white and yellow corn using either the presoaking or the traditional method (Fig. 5). The presoaking in alkali solution before cooking produced amylograph curves that are lower compared to the traditional method. The lowest peak viscosity was obtained after cooking the corn for 40–50 min after presoaking or 80–90 min using the traditional method. Both water and alkali affected starch gelatinization and amylograph maximum viscosity. The amylograph maximum viscosity data indicated that similar changes in starch granules during cooking could be achieved in shorter times when the corn was presoaked before cooking. In this experiment, a reduction of 30–35 min in cooking

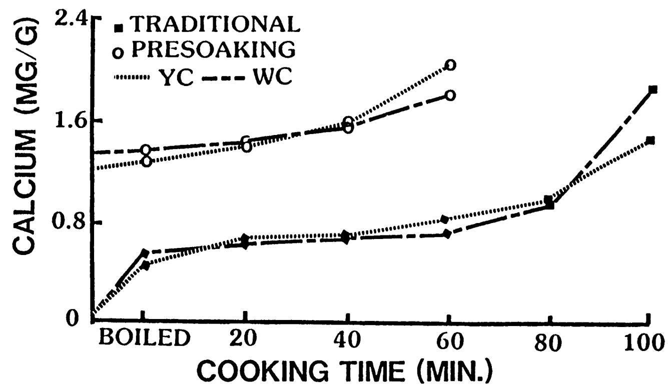

Fig. 3. Calcium uptake (mg/g) during cooking of white (**WC**) and yellow (**YC**) corn. (C.V. ranged from 4.28 to 6.25.)

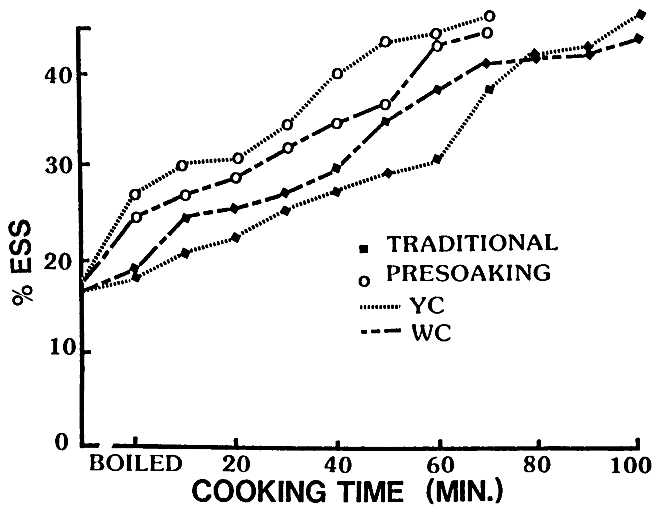

Fig. 4. Enzyme-susceptible starch % (**ESS**) during cooking of white (**WC**) and yellow corn (**YC**). (C.V. ranged from 2.69 to 7.29.)

time was obtained by the presoaking method to achieve similar amylograph peak viscosity.

Scanning electron microscopy showed that the starch granules from the floury endosperm of white corn of the presoaked sample

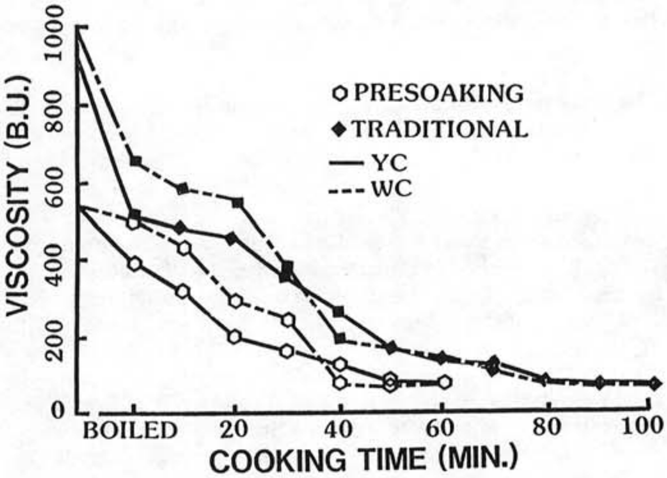

Fig. 5. Amylograph maximum viscosity in BU during cooking of white (**WC**) and yellow corn (**YC**). (C.V. ranged from 5.26 to 9.25.)

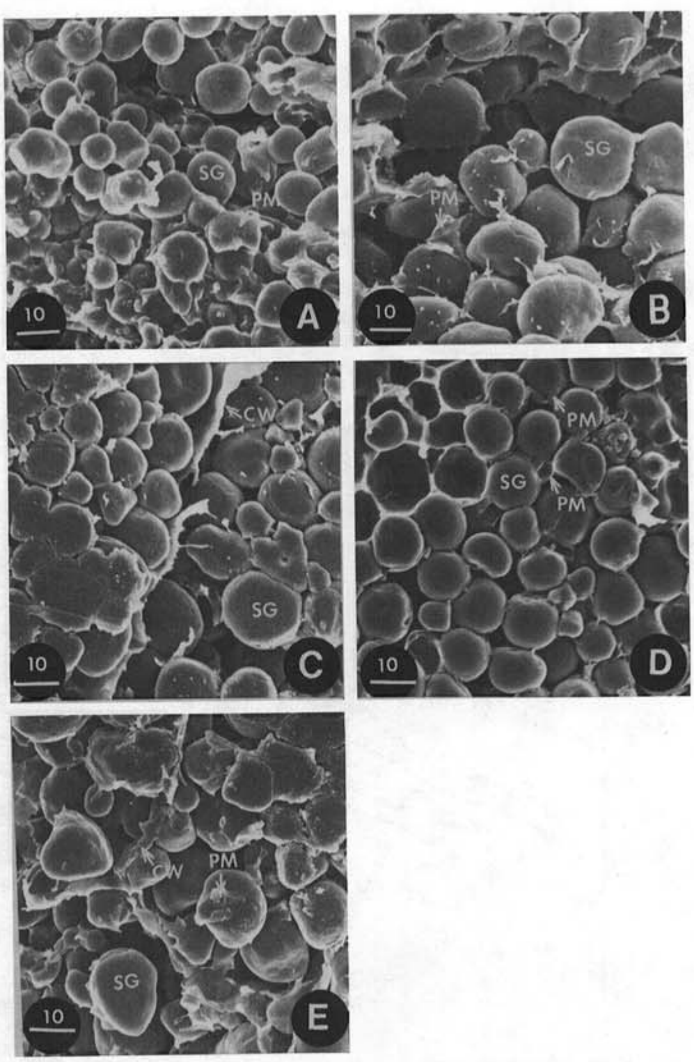

Fig. 6. Starch granules of the floury endosperm of corn kernel at boiling using the traditional (**A**) or presoaking methods (**B**), after cooking 30 min using the presoaking method (**C**), or after cooking 60 (**D**) or 100 min (**E**) using the traditional method. **SG**, starch granule; **CW**, cell wall of corn kernel; and **PM**, protein matrix.

at boiling (Fig. 6A) were expanded more than those from the traditionally cooked sample at boiling (Fig. 6B). The protein matrix also appears to be more degraded in the presoaked sample. Presoaking and cooking for 30 min produced much larger starch granules compared to 60 min cooking in the traditional procedure, indicating higher water uptake (Fig. 6C and D). After cooking 100 min using the traditional method (Fig. 6E), the starch granules appeared similar in size and shape to the starch granules after cooking 30 min using the presoaking method. The scanning electron microscopy analysis demonstrated that changes in structure could be achieved in shorter cooking time if corn was presoaked first compared to the traditional alkali method of cooking corn.

CONCLUSIONS

Soaking white or yellow corn before cooking allowed better water and alkali imbibition, softened the corn kernel, and reduced the cooking time for tortilla preparation from 80 to 50 min. The presoaking procedure allowed most of the chemical and physical reactions to take place faster. By this method, a reduction of up to 40% of the energy expended during alkali cooking of corn can be achieved and produce a similar quality product.

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