Cooking Characteristics of Sorghum and Corn for Tortilla Preparation by Several Cooking Methods

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ABSTRACT

Various methods of cooking affected the total dry matter lost during the processing of corn and sorghum into tortillas. However, within a cooking method, the total dry matter losses were the same for sorghum (*Sorghum bicolor* L. Moench) and corn (*Zea mays* L.) when each grain was cooked for its optimum time. Unpearled and pearled sorghum required only one third and one sixth the cooking time of corn, respectively. The chemical composition of grain, *nixtamal, masa*, and tortillas made from unpearled white sorghum or white corn was similar, except that the corn products had more ether extract. The sorghum tortillas, however, were greenish yellow compared to those from white corn. The greenish yellow color disappeared when 13% of the initial kernel weight was removed by pearling, and the tortillas thus resembled white corn tortillas. For pearled sorghums, the cooking time and the alkali concentration were reduced considerably to control the stickiness of *masa*. Because sticky *masa* cannot be formed into tortillas with the commercial equipment available, several procedures to prevent stickiness are suggested. Larger amounts of sorghum and pearled sorghum could be substituted for yellow corn than for white corn. Tortillas made by substituting white or red pearled sorghum for 80% of yellow corn were better accepted by panel members than the 100% yellow corn tortillas. Mexican taste-panel members preferred white tortillas, whereas U.S. consumers preferred yellow. The manipulation of the cooking conditions, the pearling level, and the ratios of corn to sorghum can lead to effective utilization of sorghum, alone or blended with corn for tortillas.

In Mexico and Central America, tortillas are an important staple bread in terms of nutrition and economics. Tortillas are an unleavened, flat bread produced by cooking corn in alkali (calcium hydroxide), steeping, and washing the cooked corn (*nixtamal*). Then, the *nixtamal* is ground into *masa*, formed into thin, flat dough pieces, and cooked into tortillas. In the United States, several cooking methods are used to produced *masa* (Bedolla and Rooney 1982), but the basic steps of nixtamalization are the same as those used in Mexico. Although corn is preferred for tortillas, it is sometimes replaced by sorghum in regions of Honduras, El Salvador, and Guatemala, depending on corn price and availability (Futrell et al 1982). In diets of rural Mexicans, corn tortillas comprise nearly 70% of daily calorie and protein intake (Chavez 1972). Because sorghum is the second leading cereal crop in Mexico, improved varieties could be substituted for corn to produce tortillas (Khan et al 1980).

Although corn and sorghum are similar in composition (Rooney et al 1980), sorghum contains polyphenols, which produce unacceptable colors when sorghum is cooked in alkali. Pearling sorghum to remove the pericarp, which contains most of the polyphenols, is one way to improve the color of sorghum tortillas (Anderson and Burbridge 1971; Reichert and Youngs 1976, 1977; Rooney and Sullins 1969). Johnson et al (1980) used pearled sorghum to produce instant dry flours for tortillas. Pearled red or white sorghums have been used in African and Asian foods (Badi et al 1981, Desikachar 1980), but their use in tortillas has not been documented. We used three cooking methods to compare properties of unpearled and pearled sorghum for tortilla manufacturing against those of white and yellow corn. Improvement in the color of sorghum tortillas by process modification is also reported.

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MATERIALS AND METHODS

Grain Samples

A commercial white dent (Asgrow 403W) and a yellow dent corn hybrid (Asgrow 404), grown under irrigation in Uvalde, TX, were used. Two sorghums grown at the Styles Farm near Thrall, TX, in 1978—Funks G766W, a white sorghum with thick mesocarp, pigmented stylar area, and heteroyellow endosperm; and TAM680 (TAM428 × Redlan), a red sorghum with a thin, red pericarp and a nonyellow endosperm—were used. A white (CS3541) and a red (A399×T×430) sorghum grown near Halfway, TX, in 1980, were also used. All grain samples were free of cracked kernels and had no significant mold, staining, or insect damage. The red sorghums are considered yellow sorghums, according to U.S. Grain Standards, whereas the white sample meets the standards for U.S. white sorghum. The hybrids, TAM680 and A399×T×430, represent the typical U.S. yellow sorghums available commercially. All samples were stored at −4°C until used.

Experiment I: Corn and Sorghum Comparisons

In the first experiment, an operator used a traditional and a steam-cooking method to compare the dry matter loss (DML) of white corn, yellow corn, and three types of sorghum (white Funks G766W, white CS3541, and red A399×T×430) (Table I).

Using the same conditions and equipment, a second operator repeated the evaluations approximately six months after the first operator had completed the cooking trials. Comparisons between white corn and white sorghum Funks G766W were made by measuring the chemical composition of grain, *nixtamal*, and *masa*, and the color and texture (Instron) of tortillas.

Traditional Cooking

Sorghum or corn was cooked according to method 1 (Table I). A 1.0-kg sample of sorghum or corn was placed in a covered 21-L cooker (Sears model 620.46010). After the mixture of grain, alkali, and water reached the boiling point, the corn and sorghum were cooked for 70 and 25 min, and steeped in the cooker for 15 and 4 hr, respectively. Each grain was then thoroughly washed with tap water (final water pH, 8.0), and the *nixtamal* was stone-ground to *masa* and made into tortillas according to the methods of Khan et al (1982).

Steam Cooking

For the steam-cooking method (Table I, method 2), grain and a measured amount of alkali and water were placed in a covered, steam-jacketed kettle (Groen model TDC12). The mixture was brought to a boil, which usually occurred 5.0 min after steam (15 psi) was injected into the jacket of the kettle. The optimum cooking time for a particular grain was recorded from the time of initial boiling until the steam was stopped. Sorghum was washed immediately with cold tap water. Corn was steeped in the kettle for 4 hr. Methods of Khan et al (1982) were followed in the processing of *nixtamal, masa*, and tortillas.

Experiment II: Pearled Sorghum for Tortillas

The objective of the second experiment was to improve the color of tortillas by removing the sorghum pericarp and by optimizing the cooking conditions. The DML and chemical composition of white corn, unpearled sorghum, and pearled sorghum products (*nixtamal, masa*, and tortillas) were compared. Changes in tortilla color as the pearling level increased were contrasted to those of white corn tortillas.

Pearling

Grain of a red (TAM680) and a white (Funks G766W) sorghum was pearled in a modified Strong-Scott barley pearler (Rooney and Sullins 1969) until 13% (Funks G766W = 28 sec; TAM680 = 35 sec) and 25% (Funks G766W = 48 sec; TAM680 = 50 sec) of the initial weight was removed. The pearled sorghums were cleaned to remove fine particles of bran and endosperm.

Cooking with the Reflux-Condensing System

A 250-g portion of either sorghum or corn was placed into a 600-ml beaker that contained alkali and water (Table I, method 3). The cooking equipment used was a crude fiber reflux condensing device. After the mixture reached its boiling point, the grain was optimally cooked and steeped (if required) in the beaker.

Methods of Khan et al 1982 were followed for washing *nixtamal*, grinding *nixtamal* to *masa*, and preparing tortillas.

Experiment III: Corn-Sorghum Blends for Tortillas

The objective of the third experiment was to determine how much sorghum could be substituted for white or yellow corn. White or yellow corn (control), unpearled white sorghum (CS3541), 13% pearled white sorghum (PWS, CS3541), and 13% pearled red sorghum (PRS, A399×TX430) were individually cooked with the traditional method (Table I, method 1). The cooked corn and unpearled sorghum were allowed to steep in the cooker. No steeping was required for the pearled sorghums. Each grain was cooked and ground into *masa* separately. Next, sorghum *masa* replaced 0, 20, 40, 60, 80, and 100% of the corn *masa*. Each mixture was blended in a KitchenAid Hobart mixer (model 572F) for 1 min at high speed. The tortillas were compared with the appropriate controls for color, texture (Instron), and acceptability. Based upon the results of these initial trials, the most promising blends of corn and pearled sorghum were evaluated by a 10-member taste panel.

Sensory Evaluation of Tortillas

Tortillas from each of three selected sorghum-corn blends were distributed at random among each of 10 sensory panel members from Mexico. The properties evaluated were color, texture (rollability), and taste. A 9-point hedonic scale (Peryam and

TABLE I
Parameters Used to Prepare Corn and Sorghum *Nixtamal* by Three Cooking Methods

Cereal Grain	Cooking Method[a]	Sample Size (kg)	Grain-Water Ratio (w/w)	Alkali[b] (%)	Cooking Time (min)	Steeping Time at RT[c] (hr)
Experiment I						
White or yellow corn	Traditional (1)	1.0	1:3.0	1.0	70	15
	Steam cooking (2)	3.0	1:3.0	1.0	90	4
Unpearled sorghum						
Funks G766W	Traditional (1)	1.0	1:3.0	0.8	25	4
CS3541						
A399×TX430	Steam cooking (2)	3.0	1:3.0	0.8	30	0
Experiment II						
Unpearled sorghum						
Funks G766W	Reflux system (3)	0.25	1:3.0	0.4	25	4
TAM680						
Pearled sorghum[d]						
13% Funks G766W	Reflux system (3)	0.25	1:1.2	0.1	15	0
13% TAM680						
25% Funks G766W						
25% TAM680	Reflux system (3)	0.25	1:1.2	0.1	10	0
White corn	Reflux system (3)	1.0	1:3.0	1.0	70	15
Experiment III						
White or yellow corn	Traditional (1)	1.0	1:3.0	1.0	70	15
Unpearled CS3541	Traditional (1)	1.0	1:3.0	1.0	90	4
13% pearled CS3541	Traditional (1)	1.0	1:1.2	0.1	15	0
13% pearled A399×TX430	Traditional (1)	1.0	1:1.2	0.1	15	0

[a]The number in parenthesis corresponds to the number of the cooking method cited in the text.
[b]Alkali concentration was based on the grain weight.
[c]RT = room temperature.
[d]The 13 and 25% refers to the amount of grain removed by the pearling procedure.

Pilgrim 1957), where 1 = dislike extremely and 9 = like extremely, was used to evaluate each property. The experiment was repeated on three different days, and the separation of the mean scores was made by the least significant difference method.

Texture of Tortillas

A Kramer Shear Cell (KSC) attached to an Instron model 1122 testing machine was used to determine the texture of tortillas. The design of the KSC resembles the human mastication mechanism to some extent. After the tortillas were cooked, they were packed in a plastic bag and stored at 25°C and 60% rh over a period of 48 hr. One 50-cm^2 strip from each of five tortillas was placed into the KSC and sheared at a crosshead speed of 50 mm/min. A 454-kg load cell was used for all measurements, and texture was expressed as maximum peak-shear in newtons. The precision of the KSC in measuring tortilla texture was evaluated by determining the texture of 50 corn tortillas produced by a local tortilla manufacturer. The coefficient of variation for the method was 9.8%.

Chemical and Physical Analyses

Dry matter losses, starch content, and enzyme-susceptible starch (ESS) were determined by the methods of Khan et al (1982). The color was determined with a Hunter Lab color meter. An index, $E = (L^2 + a^2 + b^2)^{1/2}$, was reported. The higher the E value, the whiter the tortillas. Moisture and protein content were determined by standard AACC (1976) procedures. Calcium, phosphorus, ether extract, and crude fiber were analyzed by AOAC (1975) standard procedures.

Experimental Design

Analyses of variance were made on a completely randomized experimental design. Every cooking experiment was repeated on each of three different days, and two observations for each property measured were taken within each of three days. The least significant difference method was used to test for significant differences between the means.

RESULTS AND DISCUSSION

Experiment I: Corn and Sorghum Comparisons

DML is of significant importance because of pollution and loss of materials. Sorghum (Funks G766W, CS3541, and A399×TX 430) and corn had similar DMLs (Table II) when processed with either of the two cooking methods. However, the steam-cooking method caused lower DML than the traditional method for either sorghum or corn. For instance, the average DMLs for sorghum, white corn, and yellow corn were 12.4, 13.9, and 10.0% for the traditional method and 5.6, 7.0, and 5.7% for the steam-cooking method, respectively. Bressani et al (1958) reported DMLs for white and yellow corn cooked by traditional procedures of 12.6 and 9.5%, respectively. The DMLs determined by each of the two operators were comparable, suggesting that the methods were repeatable. The largest variation in DML was for CS3541 sorghum. This might be because of the more thorough washing and rubbing of the *nixtamal* after steeping, which would have removed greater amounts of pericarp and germ. Sorghum required approximately one third the cooking time of corn by either the traditional or the steam-cooking method and only one fourth the

TABLE II
Dry Matter Loss During the Cooking of Corn and Sorghum as Affected by Operator and Cooking Methods (Experiment I)[a]

		Dry Matter Recovery (%)[b]			
		Traditional Method		Steam-Cooking Method	
Cereal	Operator	Wash and Steep Waters	*Nixtamal*	Wash and Steep Waters	*Nixtamal*
White corn	One	14.5 ± 1.3	84.1 ± 1.9	8.3 ± 1.3	94.7 ± 3.1
	Two	13.3 ± 1.4	87.4 ± 2.8	5.7 ± 0.8	91.9 ± 1.4
Yellow corn	One	9.5 ± 1.2	91.5 ± 1.4	7.1 ± 1.1	92.4 ± 0.6
	Two	10.4 ± 1.4	92.7 ± 2.1	4.3 ± 0.4	98.1 ± 0.7
White sorghum CS3541	One	10.8 ± 0.8	91.8 ± 0.9	5.0 ± 0.4	95.8 ± 1.2
	Two	14.7 ± 0.6	84.2 ± 1.8	4.7 ± 0.6	93.4 ± 0.8
White sorghum	One	12.6± ±0.6	90.1 ± 1.1	...	...
Funks G766W	Two	11.3 ± 0.9	92.8 ± 2.1	...	...
Red sorghum	One	13.2 ± 0.5	91.2 ± 1.7	6.1 ± 0.2	92.1 ± 1.2
A399×TX430	Two	11.8 ± 1.6	92.1 ± 1.3	6.4 ± 1.6	94.2 ± 2.4

[a]Two different scientists replicated the cooking experiment on three different days with two determinations of dry matter loss within each day.
[b]Expressed on dry weight basis.

TABLE III
Experiment I: Mean[a] Composition and Color of Products from Unpearled White Sorghum and White Corn Cooked by the Traditional Method

	Grain		*Nixtamal*		*Masa*		Tortilla	
Property	Corn	Sorghum	Corn	Sorghum	Corn	Sorghum	Corn	Sorghum
Moisture, %	12.0	11.3	50.5	53.4	51.0	51.4	36.2	41.2
Crude protein, % (N × 6.25)	10.3	10.4	10.6	11.0	10.8	11.4	10.8	11.3
Crude fiber, %	1.7	1.8	0.8	0.9	...	...	0.8	0.9
Ether extract, %	5.0	3.8	3.1	2.7	...	...	3.6	2.3
Starch, %	76	75	79	77	79	82	80	84
ESS[b]	240	252	420	392	475	458	584	614
Minerals,[c] (%)	0.1	0.1	0.6	0.4	...	...	0.6	0.4
Color[d] (E)	67	65	63	51	71	58	69	57

[a]Expressed as mean of three replicates on dry weight basis. The least significant difference ($\alpha = 0.05$) values for the properties measured were the following: moisture, 1.8; crude protein, 1.7; crude fiber, 0.2; ether extract, 0.3; starch, 2.2; ESS, 32.0; minerals, 0.1; and color, 3.1.
[b]Enzyme-susceptible starch was expressed as milligrams of glucose per gram of starch.
[c]Only calcium and phosphorus were determined.
[d]$E + (L^2 + a^2 + b^2)^{1/2}$ where L = white; −a = green; +a = red; and b = yellow.

steeping time by the traditional method. Steam-cooked sorghum did not require steeping. The reduce cooking and steeping times for sorghum could save significant energy and time for both the village housewife and commercial plants.

Physical and Chemical Properties

The chemical composition (Table III) of traditionally cooked sorghum (Funks G766W) and white corn products (ie, grain, *nixtamal, masa,* and tortillas) was similar, with only two exceptions. All the sorghum products had less ether extract, and sorghum tortillas retained more moisture after cooking than corn tortillas. Excess moisture can shorten shelf life. The ether extract and crude fiber decreased in *nixtamal* because large amounts of germ and pericarp were lost during cooking, steeping, and washing. The amount of ESS increased as the grain was processed. There were no significant differences, however, between corn and sorghum products. Corn products had the highest levels of calcium and phosphorus, probably because more alkali was used to nixtamalize corn than sorghum.

In general, the color of unpearled white sorghum products was darker than that of white corn products. For instance, sorghum tortillas had a slight greenish yellow color presumably produced by unknown reactions of polyphenols with the alkali.

The tortillas from unpearled white sorghum had lower peak-shear values (Fig. 1) and were softer and more flexible than corn tortillas made in the laboratory and by a commercial manufacturer. These data suggest that the laboratory tortillas did not become stale as rapidly as the commercial tortillas. Higher moisture content of sorghum tortillas may explain the consistently lower peak-shear forces.

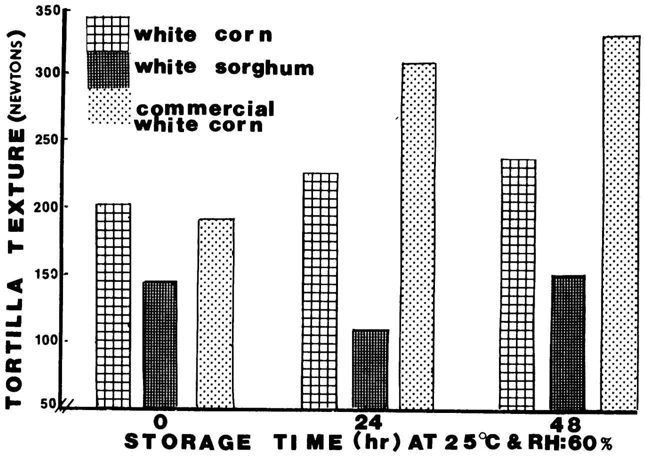

Fig. 1. Effect of storage on texture of unpearled white sorghum and white corn tortillas (Experiment I).

Experiment II: Pearled Sorghum Grain for Tortillas

Dry Matter Losses. Pearled sorghum required less cooking time and had less DML than corn (Table IV). As the pearling level increased, the cooking time decreased from 25 min for unpearled sorghum to 15 and 10 min for 13 and 25% pearled sorghums, respectively. The optimum cooking time for corn was 70 min. Because pearled sorghums received less cooking and no steeping, the mean DML was 7.0% compared to 12.0% for white corn and 10.1% for yellow corn. The expense of pearling may be partially compensated by selling the bran for livestock feed, thus making sorghum more competitive with corn in the manufacturing of tortillas.

Physical and Chemical Properties

Pearled sorghum tortillas had a higher content of ESS and protein and more total starch than the corn tortillas (Table IV). The higher ESS for the pearled sorghum resulted because the sorghum endosperm and starch granules were more exposed to the boiling alkali solution, thus leading to more rapid water uptake, more extensive starch gelatinization, and granule disruption. Starch and protein are the main components of the pearled sorghum, which was nearly pure endosperm. The higher levels of water uptake and starch gelatinization by the pearled sorghums may partially explain the development of sticky *masa.* Sticky *masa* is undesirable for industrial operations because the formation of tortillas is nearly impossible, but fortunately there are several ways to eliminate the stickiness of sorghum *masa.* One way is to reduce the concentration of alkali and increase the cooking time. A second way is to reduce the amount of water and alkali concentration at the same time. For instance, pearled sorghum could be cooked with limited water and low levels of alkali (ie, 0.05–0.2%), which would eliminate DML because washing would not be necessary. A third way to control the stickiness might be the addition of small amounts of wheat flour or dry nixtamalized corn or sorghum flour. A fourth way is to allow the sorghum *masa* to stand for 45 min at 25°C. A fifth way is to blend the pearled sorghum *masa* with corn *masa.* Since pearled sorghum requires low amounts of alkali, blending it with corn *masa* would increase the level of available calcium, a mineral needed by Mexican and Central American populations.

Tortillas made from 25% PWS were as white as tortillas from white corn and whiter than those made with yellow corn (Table IV). Even the 13% PWS tortillas were whiter than yellow corn tortillas. Unlike the yellow endosperm sorghums and yellow corn, white sorghums do not contain carotenoid pigments in the endosperm. Tortillas from the 25% PRS were darker than white corn tortillas but similar to those of yellow corn. The lack of whiteness was probably due to the remnants of red pericarp in some grains

TABLE IV
Experiment II: Mean[a] Dry Matter Loss (DML), Composition and Color of Tortillas from Pearled[b] Sorghum and Corn Cooked with the Reflux Condensing System

	Type of Sorghum[b]							
	White	Red	White	Red	White	Red	Corn	
Pearling Level	0%		13%		25%		White	Yellow
DML,[c] %	9.1	8.0	6.5	7.7	6.4	7.5	12.0	10.1
Crude protein, % (N × 6.25)	11.4	11.0	11.9	11.8	12.2	10.8	10.5	9.8
Moisture, %	42.1	45.4	48.6	44.3	45.3	45.0	44.0	44.7
ESS[d]	496	481	562	570	576	594	428	452
Starch, %	75	76	77	78	79	80	69	72
Color (E)[e]	63	54	67	59	70	61	71	62

[a] Expressed as mean of three replicates on dry weight basis. The least significant difference ($\alpha = 0.05$) for the properties measured were the following: DML, 1.3; protein, 1.2; moisture content, 1.8; ESS, 26; starch, 2.2; and, color, 3.1.

[b] A white sorghum, Funks G776W, and a red sorghum, TAM680, were pearled each at 0, 13, and 25% level.

[c] DML expressed on dry weight basis.

[d] Enzyme susceptible starch was expressed as milligrams of glucose per gram of starch.

[e] $E = (L^2 + a^2 + b^2)^{1/2}$ where L = white; −a = green; +a = red; and b = yellow.

because of the inherent structure of the sorghum kernel (Rooney et al 1980). Complete removal of the pericarp from all the kernels was nearly impossible, even at the 25% level. Therefore, the manipulation of the cooking conditions or the utilization of red sorghum-corn blends are an alternative to better tortilla colors. Pearling to remove 25% of the kernel would not be practical because of the power consumption and the losses of dry matter as bran.

Experiment III: Corn-Sorghum Blends for Tortillas

Color and Texture of White Corn-Sorghum Tortillas. The objective was to provide an alternative use of sorghum for tortillas without removing high amounts of pericarp as bran. Blending corn and sorghum *masa* was a practical way to decrease the slight greenish and pinkish tortilla color produced by unpearled white sorghum and 13% PRS, respectively. The Hunter Lab color meter used to measure the color of tortillas provided reproducible results (SD = 1.2, CV = 2.5%). This method should be complemented, however, with data from sensory panel tests to allow comparisons among the blends. For instance, solely in terms of color (Fig. 2), unpearled white sorghum or 13% PRS each replaced 20% of white corn *masa*, whereas 13% PWS replaced 40% white corn *masa*. Higher substitution levels of sorghum for corn were acceptable when the overall appearance of tortillas was evaluated by the sensory panel.

The Instron texture of fresh tortillas (0 hr storage) made from white corn-pearled sorghum blends was as soft as or softer than that of white corn tortillas (Fig. 3A, B). Either red (13% PRS) or white (13% PWS) pearled sorghum replaced up to 80% corn *masa*, without affecting the texture of tortillas at 24 and 48 hr of storage.

Sensory Evaluation of Tortillas

All combinations (Table V) of white corn:13% PWS or white corn:13% PRS produced tortillas as acceptable as white corn tortillas. The tortillas made from all combinations of yellow corn:13% PWS or yellow corn:13% PRS were more acceptable than yellow corn tortillas. In short, either of the two pearled sorghums could replace up to 80% of either yellow or white corn. Sensory evaluation confirmed the fact that a majority of Mexican consumers prefer white over yellow tortillas, whereas U.S. consumers prefer yellow tortillas.

CONCLUSIONS

The reduced cooking and steeping times for sorghum are advantages that could lead to significant savings of energy and time at both the village and the commercial levels. The DMLs of sorghums were similar to those of corn with each of the three cooking methods. Regardless of the cooking method, the composition of sorghum tortillas was similar to that of corn tortillas. Unpearled white sorghum tortillas were softer than white corn tortillas. Removal of the sorghum pericarp by pearling caused a significant reduction in cooking time and an improvement in the color and acceptability of tortillas. According to a sensory evaluation of tortillas, U.S. red pearled sorghum could replace 80% of white or yellow corn. The U.S. white pearled sorghum could replace even more corn if the color of the grain were acceptable. Mexican taste panelists preferred white tortillas over the yellow tortillas, but for U.S. panel members, yellow corn tortillas were more acceptable. Therefore, a manipulation of the cooking conditions, the pearling level, the corn to sorghum ratios, and the variety of sorghum, can lead to successful use of sorghum in both Mexican and U.S. tortillas. These results suggest that sorghum can be used effectively alone or in blends with corn to produce tortillas

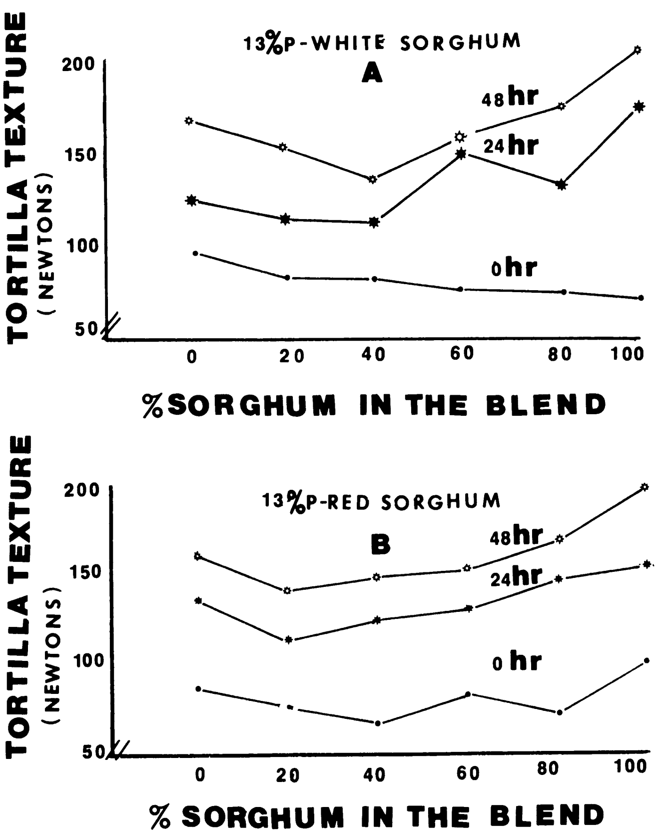

Fig. 3. Effect of storage on texture of tortillas from pearled sorghum-white corn blends (Experiment III).

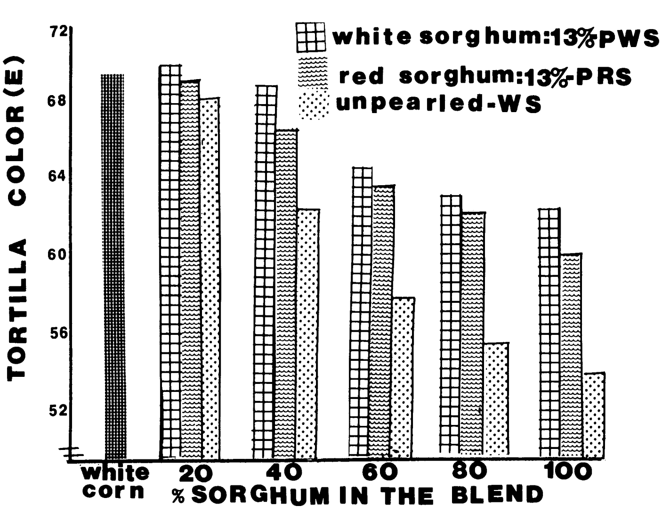

Fig. 2. Color of tortillas from sorghum-white corn blends (Experiment III).

TABLE V
Experiment III: Mean[a] Scores for Acceptability of Tortillas Made from Corn-Pearled Sorghum[b] Blends

Percent Sorghum in the Blend	Scores Given to Blends of Sorghum and White Corn	Yellow Corn
White pearled sorghum (13% PWS)		
0	7.5	5.2
40	7.8	6.4
60	7.2	8.0
80	7.4	5.0
Red pearled sorghum (13% PRS)		
0	7.5	5.2
40	7.3	5.8
60	7.2	7.5
80	7.0	6.0

[a]Expressed as mean of three replicates. Least significant difference = 0.4 for $\alpha = 0.05$.

[b]A white sorghum, CS3541, and a red sorghum, A399×T×430, were pearled at a 13% level, cooked separately, and blended with each type of corn.

with acceptable color, flavor, and texture. This will depend on the quality of sorghums and the economics and relative availability of sorghum and corn.

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