NOTE

A Method to Evaluate the Lime-Cooking Properties of Corn (*Zea mays*)

S. O. SERNA-SALDIVAR, M. H. GOMEZ, H. D. ALMEIDA-DOMINGUEZ, A. ISLAS-RUBIO, and L. W. ROONEY[1]

Lime-cooked corn products (table tortillas, corn chips, and tortilla chips) are increasing in popularity worldwide. After potato chips, corn and tortilla chips are the most popular salted snack foods in the United States (Anonymous 1992). The acceptability of corn products is directly related to the cooking and processing quality of the corn kernel. Dent corns with intermediate to hard endosperm texture and bright yellow or white color are being developed especially for lime-cooked products (Serna-Saldivar et al 1990). The primary selection criteria include: test weight 77.2 kg/hl (60 lb/bu); 1,000-kernel weight > 300 g; density (determined by nitrogen-displacement pycnometry) > 1.3 g/cm^3; hardness (percent of material removed by abrasion) < 40%; and easily removable pericarp (Rooney and Bockholt 1987). In actual practice, the ideal kernel characteristics are not available in most parts of the United States. However, this is the ideal to strive toward for development of good food corns.

Corn for tortillas is cooked in a lime solution at 85–100°C for 10–40 min and steeped for 12–16 hr. The extent of cooking is commonly subjectively rated by evaluation of the texture of cooked, hydrated corn kernels (nixtamal) and the degree of pericarp removal. A standard method to evaluate pericarp removal has been reported by Serna-Saldivar et al (1991). The most important control factor is the degree of cooking, because it greatly affects masa machinability, tortilla properties, and yield of product. Information on a nylon-bag technique developed to determine optimum cooking time and dry matter losses of corn during alkaline processing is described.

[1]Cereal Quality Laboratory, Department of Soil and Crop Sciences, Texas A&M University, College Station.

MATERIALS AND METHODS

Grain

Eleven corn samples with contrasting physical properties were selected for evaluation (Table I). Except for the export corn, all corn samples were obtained from commercial seed companies. They were food corn hybrids grown in west Texas under irrigation in replicated trials. The export corn was obtained from the Port of New Orleans and was a blend of yellow dent corn hybrids grown primarily for feed.

Physical Properties of Corn Samples

Foreign material, impurities, and broken kernels were removed from the corn samples before evaluations. Clean grains were characterized for test weight, 1,000-kernel weight, hardness, and grain density. Test weight was determined using a Winchester bushel meter with a 1-L cup. Hardness was objectively measured as percent of material removed after subjecting 40 g of sample to abrasion for 10 min in a tangential abrasive dehulling device (model 4E-115, Venables Machine Works, Saskatoon, SK, Canada) equipped with an aluminum oxide abrasive wheel (38A36-LSVBE) and an eight-hole base. The higher the value, the softer the corn. Grain density was determined using a nitrogen comparison multipycnometer (model MUP-1 S/N 232, Quantachrome Corp., Syosset, NY). All corn samples had been allowed to equilibrate to a 11.0% moisture level.

Nylon-Bag Alkaline Cooking Test

Water (50 L) was brought to a gentle boil (98°C) in a covered steam kettle. Then 166.6 g of reactive lime (CaO reagent powder, Matheson Coleman & Bell Manufacturing Chemists, Norwood, OH) was added and mixed thoroughly in the hot water. Quadruplicate corn samples of 100 g were weighed with an accuracy of 0.1 g, placed in perforated (36 holes/cm^2) nylon bags (17.0 $\times$ 12.5 cm), and cooked for 0, 15, 30, and 45 min at 98°C. The total grain mass in the steam kettle was kept constant at 12 kg to maintain consistent heating conditions. Sample bags assigned to a given cooking time were placed in a large, perforated nylon bag. The large nylon bags were added successively at 15-min intervals, and the lime solution and nylon bags were agitated with a paddle every 5 min. Samples assigned to the 0-min cooking schedule were added to the steam kettle immediately after the steam valve was shut off. Then, cooked corns were allowed to steep for 14–16 hr, taken from the cooking bags, washed with running tap water in a colander for 40 sec, blotted between paper towels, and weighed. The wet nixtamal was returned to the cooking bag and dried for 48 hr in a forced-air oven set at 100°C. The dried nixtamal was weighed after cooling 30 min in a desiccator.

Dry matter loss (DML) and nixtamal moisture (NM) contents were calculated as:

$$\text{DML} = [(\text{Dry grain weight} - \text{dry nixtamal weight}) / \text{dry grain weight}] \times 100$$

$$\text{NM} = [(\text{Wet nixtamal weight} - \text{dry nixtamal weight}) / \text{wet nixtamal weight}] \times 100$$

Optimum cooking times (OCT) required to increase the moisture content of corn kernels to 50%, and the corresponding DML values, were predicted from NM and DML values, respectively, of corn cooked for different times using simple linear regression.

Experimental Design and Statistics

One-way analysis of variance in a completely randomized experimental design was used to evaluate the effect of corn type on the physical characteristics of kernels. Protected Fisher's least significant difference was used for multiple mean comparisons. Simple linear regression was used to evaluate the relationships between optimum cooking times and grain properties. PROC RSQUARE procedure was used to select best predicting variables (Freund and Littell 1986).

RESULTS AND DISCUSSION

The corn hybrids differed in grain physical properties and pericarp removal values (Table I). The export corn had the lowest test weight and density. Cargill 8707 retained the most pericarp, followed by the export corn. Dekalb 703W and Garst 8344 corns had the lowest and highest 1,000-kernel weight, respectively. Overall these hybrids represented typical food corns.

For all corns, the NM increased as cooking progressed (Table II). The export corn and Cargill 147003 absorbed the lime solution at the fastest rate. After being cooked 45 min, those corns absorbed 5–10 percentage points more water than the other samples. The rapid water uptake was related to their softer endosperm (r =

TABLE I
Physical Properties and Pericarp Removal of Dent Corns

Hybrid	Color	Test Weight (kg/hl)	1,000-Kernel Weight (g)	Density (g/cc)	Hardness[a] (%)	Pericarp Removal[b]
Asgrow 404	Yellow	79.5	322.5	1.329	35.4	1.8
Asgrow Rx947	Yellow	78.4	287.5	1.300	35.9	1.5
Asgrow Rx956	White	81.6	251.5	1.329	34.7	1.0
Cargill 8707	Yellow	79.8	305.0	1.335	39.2	4.5
Cargill 147003	Yellow	78.5	268.5	1.317	46.8	2.5
Frontier 5050	Yellow	85.0	337.5	1.340	41.3	1.8
Dekalb 703W	White	76.3	230.0	1.320	41.1	2.0
Garst 8344	Yellow	76.8	359.2	1.309	39.7	2.3
Conlee 117W	White	81.7	300.0	1.305	32.5	2.0
Conlee 8631	Yellow	80.2	297.5	1.299	33.7	2.0
Export	Yellow	74.3	295.0	1.294	43.9	3.5
Least significant difference (0.05)	...	0.6	7.4	0.001	0.3	0.3

[a] Percentage of weight removed after abrasive milling. Lower values correspond to harder grains.
[b] Pericarp removal was rated on a 1–5 scale, where 1 = all pericarp removed and 5 = all pericarp attached (Serna-Saldivar et al 1991).

TABLE II
Effect of Corn Type and Cooking Time on Nixtamal Moisture Content, Optimum Cooking Time, and Dry Matter Losses (DML)

Hybrid	Nixtamal Moisture Content, %, for Cooking Times, min				Regression Equations[a]	R^2[b]	OCT[c] (min)	DML[d]	DML, %, at Cooking Times, min			
	0	15	30	45					0	15	30	45
Asgrow 404	44.6	47.7	50.2	53.8	$Y = 4.96\,X - 221.0$	0.99	27.1	9.2	7.20	8.48	9.00	10.73
Asgrow Rx947	45.3	46.8	49.8	51.8	$Y = 6.57\,X - 295.6$	0.99	32.9	6.2	5.40	5.77	6.07	6.53
Asgrow Rx956	45.7	48.0	51.1	53.9	$Y = 5.39\,X - 245.6$	0.99	24.3	7.4	6.15	6.76	7.58	8.68
Cargill 8707	45.1	47.7	51.2	55.4	$Y = 4.31\,X - 192.5$	0.99	23.2	9.4	6.98	9.05	10.03	11.22
Cargill 147003	51.0	53.7	58.5	60.4	$Y = 4.43\,X - 225.2$	0.98	0.0	7.7	7.65	10.02	12.00	14.17
Frontier 5050	44.8	46.2	48.6	51.5	$Y = 6.52\,X - 288.9$	0.98	37.1	8.9	6.86	7.72	8.65	9.25
Dekalb 703W	44.5	47.7	49.1	51.5	$Y = 6.55\,X - 293.2$	0.98	34.5	7.7	5.17	6.35	7.36	8.41
Garst 8344	45.4	47.7	51.7	53.4	$Y = 5.24\,X - 237.1$	0.98	24.8	8.7	6.72	8.00	9.24	10.24
Conlee 117W	44.5	46.3	48.5	50.9	$Y = 6.98\,X - 309.5$	0.99	39.6	8.5	6.10	7.31	8.22	8.64
Conlee 8631	44.7	46.9	50.2	52.4	$Y = 5.64\,X - 251.5$	0.99	30.7	6.3	5.08	5.58	6.49	6.83
Export	54.0	56.0	59.3	63.3	$Y = 4.71\,X - 251.3$	0.99	0.0	9.7	9.78	12.72	15.65	18.79
LSD (0.05)[e]	1.2	1.4	0.8	1.0	...	...	...	...	0.6	1.1	1.3	1.2

[a] Y = cooking time (min) required to reach X nixtamal moisture (%).
[b] R^2 = Simple linear coefficient of determination relating cooking time and nixtamal moisture content.
[c] Optimum cooking time (min) calculated to produce nixtamal with 50% moisture content.
[d] Dry matter losses calculated at optimum cooking time, grams of solids per 100 g of dry matter.
[e] Least significant difference.

0.7, $P = 0.02$). A desired nixtamal moisture target is 48–50%, because the resulting masa (stone-ground nixtamal) has acceptable plasticity, cohesiveness, and machinability (Gomez et al 1991). Hard or corneous endosperm kernels absorbed the lime solution more slowly than soft endosperm kernels (Table I). Soft, floury corns were more easily cooked, requiring a shorter cooking time to reach optimum nixtamal moisture content.

Acceptable reproducibility was obtained when cooking was done with: 1) the same number of samples tested per run, 2) lime from the same lot, and 3) constant temperature ($\pm 1°C$). It is necessary to use fresh lime because it loses its activity during storage. Asgrow 404Y, with known OCT (26–27 min) and DML (8–9%) values, was included in each run to check the accuracy of the method. Other corn samples with known properties could serve as effective controls. The main requirement is to mantain adequate quantities of the standard corn for extensive usage.

A high overall relationship ($r = 0.7$, $P < 0.01$) between cooking time and nixtamal moisture content was found. This relationship could be used with the nylon-bag technique to predict cooking times required to produce nixtamal with given moisture contents. However, the overall model including moisture contents for all corns accounted for only 49% of the total variability, which was not high enough for prediction purposes. Therefore, we determined linear regression equations for each corn obtaining correlation coefficients from 0.98 to 0.99 (Table II). These regression equations were used to calculate the optimum cooking times for each hybrid. Predicted optimum cooking times for all corns ranged from 0 to 40 min.

Nixtamal moisture content must be controlled for specific applications. Corn for table tortillas is cooked more (50–51% moisture) than corn cooked for tortilla chips (46–48% moisture). A longer cooking time is required to increase nixtamal moisture for table tortillas to obtain softer, more pliable, rollable tortillas (Serna-Saldivar et al 1990). Although we tested specific food corn hybrids, we believe this methodology can be applied to any kind of corn, including blends of different hybrids. However, the cooking conditions may have to be adjusted, because most corns will be softer than those we tested.

Optimum cooking times were correlated to physical grain properties. The most significant correlations were found with hardness ($r = -0.7$, $P = 0.01$) and test weight ($r = 0.6$, $P = 0.07$). The relationship of test weight (kg/hl) and hardness (%) with OCT was best described by the multiple regression equation:

$$\text{OCT (min)} = -449.1 + 1.63\,(\text{test weight}) + 19.4\,(\text{hardness}) - 0.26\,(\text{hardness})^2$$

$$r^2 = 0.71,\ P = 0.02$$

where hardness had the most significant effect on OCT.

Cooking time ($r = 0.5$, $P < 0.01$), pericarp removal ($r = 0.6$, $P = 0.08$), and hardness ($r = 0.6$, $P = 0.05$) were correlated to dry matter losses. The loss or removal of pericarp is a very important factor in alkaline cooking because it contributes to DML (Gomez et al 1989; Plugfelder et al 1988). The presence of pericarp remnants also affect product color, texture, and processing properties (Rooney and Bockholt 1987). Corn endosperm also contributes to DML, particularly when the corn is soft and has been abused during handling, cooking, washing, and conveying.

CONCLUSIONS

The proposed lime-cooking technique is simple and effective for evaluating cooking properties. Corn test weight and hardness were the major factors that affect cooking requirements. DML was related to amount of pericarp removed during the cooking process and grain hardness. Soft kernels have more DML from nonpericarp tissue than do their hard counterparts. The proposed technique is adequate to evaluate a large number of samples in breeding programs, and it may be adopted to optimize cooking parameters at the factory level. Obviously, more information is required to prove the utility of the method.

ACKNOWLEDGMENTS

We acknowledge partial support for this research from the Snack Foods Association, Alexandria, VA.

REFERENCES

ANONYMOUS. 1992. Snack Food Association State of the Industry Report. Snack World 49(6):SW1-SW33.

FREUND, R. J., and LITTELL, R. C. 1986. SAS System for Regression. SAS Institute: Cary, NC.

GOMEZ, M. H., McDONOUGH, C. M., WANISKA, R. D., and ROONEY, L. W. 1989. Changes in corn and sorghum during nixtamalization and tortilla baking. J. Food Sci. 54: 330-336.

GOMEZ. M. H., WANISKA, R. D. and ROONEY, L. W. 1991. Lime cooking and steeping of corn masa. Cereal Foods World 36:704.

PFLUGFELDER, R. L., ROONEY, L. W., and WANISKA, R. D. 1988. Dry matter losses in commercial corn masa production. Cereal Chem. 65:127-132.

ROONEY, L. W., and BOCKHOLT, A. 1987. Searching for kernels of truth. Snack Foods 44(10):46-48.

SERNA-SALDIVAR, S. O., GOMEZ, M. H., and ROONEY, L. W. 1990. Technology, chemistry and nutritional value of alkaline-cooked products. Page 243 in: Advances of Cereal Science and Technology, Vol. X. Y. Pomeranz, ed. Am. Assoc. Cereal Chem.: St. Paul, MN.

SERNA-SALDIVAR, S. O., ALMEIDA-DOMINGUEZ, H. D., GOMEZ, M. H., BOCKHOLT, A. J., and ROONEY, L. W. 1991. Method to evaluate ease of pericarp removal of lime cooked corn kernels. Crop Sci. 31:842-844.

[Received July 19, 1991. Revised November 1992. Accepted August 5, 1993.]