Milling and Processing Parameters for Corn Tortillas from Extruded Instant Dry Masa Flour

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ABSTRACT

A continuous extrusion process to provide instant corn flour for tortillas was evaluated. Variables investigated included two types of mill (knives and hammer) with screens with two diameters (0.5 and 0.8 mm), two types of corn (hard endosperm or normal and soft endosperm or cacahuazintle), lime concentration (0.15 and 0.25% w/w), processing moisture (45 and 48% w/w) and temperature (70, 80 and 90°C). The water absorption capacity, water solubility index, color of instant corn flour, adhesiveness of masa, tensile strength, cutting force, rollability and puffing of tortillas, were compared. Based on textural data the hammer mill with 0.8 mm sieve, normal corn type, 0.15% lime, 48% moisture and 90°C processing temperature, produced the highest quality tortillas.

Key Words: corn tortilla, corn flour, extrusion, milling

INTRODUCTION

TRADITIONAL NIXTAMALIZATION PROCESS TO MAKE MASA AND corn tortillas includes batch cooking and soaking in water of whole corn kernels with addition of calcium hydroxide (lime) in a process that requires 8 to 12 h. Industrial production of instant corn flour for tortillas depends upon an adaptation of the traditional nixtamalization process and includes nutrient losses, high cost and space disadvantages (Serna-Saldivar et al., 1990). This process requires long processing time and intensive labor, as well as producing alkaline waste water disposal problems. Investigations to overcome these problems have been reported (Figueroa et al., 1993).

Some studies have focused on alternative methods to produce corn tortillas. The use of cooker extruders as continuous reactors to convert corn to masa or instant corn flour has been reported (Irvin et al., 1991; Bazúa et al., 1979; Gómez and Aguilera, 1983; Mensah-Agyapong and Horner, 1992). In general, experimental extrusion processes have yielded corn tortillas with lower sensorial quality compared with those from the traditional process.

Martínez-Bustos et al. (1996), patented a continuous extrusion process, and an experimental low shear extruder with specific characteristics for making corn masa and instant corn flour suitable to form tortillas of good quality. Whole corn grain was ground and the corn meal was mixed with lime and water. The mixture was extruded to produce fresh masa in pellet form. The fresh masa was dehydrated in an experimental infrared (IR) tunnel dryer, to provide a moisture content of 8–10% (w/w). The dry masa was reground to prepare instant corn flour.

The dry milling steps (grains and pellets) are very important because the mean particle size, starch damage, heat transfer, water and lime diffusion during extrusion may influence characteristics of masa and textural properties of tortillas (Martínez-Bustos, et al., 1996). Good quality tortillas can be rolled in "taco" form, without damage. This characteristic has been measured by instrumental (tensile strength and cutting force) and subjective tests (rollability).

The aim of our work was to select the type of mill and screen hole diameter based on textural properties of tortilla, and to evaluate the effects of processing parameters on some properties of flour, masa and tortillas produced from the extrusion process. The processing objective was to produce tortillas with similar or better quality and functional characteristics than those produced with commercial instant corn flour.

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MATERIALS & METHODS

Materials

Commercial samples of food grade white corn, hard endosperm (normal) and soft endosperm (cacahuazintle) were used and the physical and chemical characteristics were compared (Table 1). Powdered hydrated lime (El topo, Monterrey, N.L., México) was used as alkali.

Methods

The proximate composition, 1000 kernel weight and test weight of corn samples were determined using procedures described by the AACC (1983) approved methods. The pearled index (Buendía, 1981), apparent density (Koeppe et al., 1987) , water absorption capacity (Bedolla, 1983) and water solubility index (Anderson et al., 1969) were also determined.

Mean particle size

Samples (50 g each) were used to determine the mean particle size (MPS) of corn raw flour using screens (MONT-INOX) # 30, 40, 60, 80, 100 (595, 420, 250, 177 and 149 μm respectively) and pan. The screens were placed in a RO-TAP-shaker for 10 min. The flour retained on the screen was weighed and the MPS was determined as follows:

$$MPS = (W_1d_1+W_2d_2+..... +W_5d_5)/R$$

where W_{1-5} = weight of product through each sieve; d_{1-5} = diameter of mesh for each sieve; R = total recovery.

Flour color

The flour color was determined by the Hunter *L, a, b,* method. A colorimeter (Minolta, CR-210) was used. A 100g sample was placed on a petri plate of 16 cm dia and 1 cm deep. Readings on four posi-

Table 1 — Physical and Chemical Characteristics of Raw Corn

Type of corn	1000 Kernel wt[1] (g)	Test wt[a] (kg/hL)	Pearled index[1] (%)	Protein[b,c] (%)	Lipids[b] (%)	Crude fiber[b] (%)	Ash[b] (%)
Normal	376.1	75.1	33.8	9.23	4.73	1.67	1.29
Cacahua-zintle	629.6	56.8	73.4	6.92	4.59	1.42	1.47

[a]Mean values of three or more repetitions.
[b]Mean values of three repetitions, reported on dry base.
[c]N x 6.25.

tions, 90° apart, were obtained. The *L*, *a*, and *b* values were determined, and ΔE was calculated as follow:

$$\Delta E = [(\Delta \underline{L})^2 + (\Delta \underline{a})^2 + (\Delta \underline{b})^2]^{1/2}$$

where $\underline{L}$ = brightness or lightness (100 = perfect white, to 0 = black); $\underline{a}$ = greenness/redness [negative (green) to positive (red)]; $\underline{b}$ = yellowness/blueness [negative (blue) to positive (yellow)]; $\Delta \underline{L}$, $\Delta \underline{a}$, and $\Delta \underline{b}$ = absolute differences of the values between the reference tile (white porcelain) and sample values were also recorded; ΔE = total difference between reference and sample color.

The reference values (calibration) were: $\underline{L}$ = 97.63, $\underline{a}$ = 0.78 and $\underline{b}$ = 2.85.

Apparent viscosity with RVA

A Rapid Visco Analyzer (RVA-3D) (Newport Scientific Pty, Australia) was used to measure apparent viscosity of samples as a function of temperature. All corn flour samples were passed through a #60 screen; sample moisture was determined and sample weight adjusted (3±0.001g) to 14% (m. b.). For example, if a flour sample was 12.5% (w/w.) moisture, 3g × (100-14) / (100-12.5) = 2.95g was used. After that, distilled water was added to keep the total weight (water plus sample) constant at 28 g. Rotating paddles were held at 50°C for 2 min to stabilize the temperature and ensure uniform dispersion and wetting of samples, then it was heated to 92°C at a constant rate of 5.6°C/ min. The sample was held at this temperature for 5 min and then cooled to 50°C in 7.5 min at the same rate.

Production of experimental instant corn flour

Whole corn kernels were ground with a mill (Pulvex-200) using knives and hammer head, and the corn flour was mixed with lime and water at different concentrations (see experimental design), with a domestic blender (Kitchen Aid, K5SS). An experimental single screw extruder with a low shear was used. All samples were extruded at 35 rpm with 1.8 min residence time to produce fresh masa in pellet form. The corn masa was dehydrated in an experimental IR tunnel dryer, to provide pellets with moisture content of 8-10% (w/w). The dry masa was reground (Pulvex-200) and tortillas were prepared as described by Martínez-Bustos et al. (1996).

Preparation of masa and tortillas

Instant dry masa flour (300g) was rehydrated with enough water to obtain fresh masa with adequate consistency to make tortillas. Consistency was suitable when the masa pressed between two metallic plates covered with plastic films did not stick to them. Masa was rounded and shaped in the form of flat discs using a manual form (Casa González, México, D.F.). The masa discs were baked on a hot plate about 290±10°C for 27 sec on one side, followed by 30 sec on the opposite side, and then they were turned to the first baked side and held until they puffed. Dimensions of the tortillas were: 1.2±0.1 mm thickness, 12.5±0.2 cm dia and 18±0.5 g.

Adhesiveness of masa

Adhesiveness of masa was determined using the TA.XT2 Texture Analyzer (Texture Technologies Corp., Scarsdale, NY/Stable Micro System, Godalming, Surrey. UK) with a TA-18 probe attachment. Rehydrated masa samples (50 g) were shaped in the disc form of 4±0.1 cm dia and 1.5±0.1 cm thickness and placed on the metallic flat platform. Testing conditions were a speed of 2 mm/sec, and a penetration of 4 mm deep. The peak force was recorded.

Firmness of tortillas

The TA.XT2 Texture Analyzer (Texture Technologies Corp., Scarsdale, NY/Stable Micro System, Godalming, Surrey, UK) was used to determine tensile strength and cutting force of tortillas. A sample consisting of a 3.7×9 cm strip of the middle part of a tortilla was placed on the TA-96 probe, attached to the head of the Texture Analyzer and tested for tensile strength. The texturometer head moved the probe upwards at 2 mm/sec until the tortilla broke. Two tortillas of each treatment were evaluated after 30 min at room temperature (25°C). The same strips of tortilla were placed on the platform and the TA-90 attachment was used to determine the cutting force. The texturometer head moved the probe downwards at 2 mm/sec until the tortilla was cut. The tensile strength and cutting force were expressed as peak force (kg_f) required to break and cut the strip.

Rollability and puffing of tortillas

The rollability of tortillas was determined by the Bedolla (1983) method using tortillas kept for 30 min at room temperature after being formed. The whole tortilla was rolled around a glass rod of 2 cm dia and the breakage degree was determined using a subjective scale from 1 to 5, where 1, 2, 3, 4 and 5 corresponded to breakage degrees of about 0, 25, 50, 75 and 100% of the length of the tortilla.

The puffing of tortillas was estimated observing the percentage of total surface that puffed, on a scale of 1 to 3, where 1 corresponded to complete puffing (70-100 %), 2 , medium puffing (30-70%) and 3, no puffing (0-30%).

Experimental design

A factorial arrangement to select the type of mill was used, evaluating type of corn (normal and cacahuazintle), type of mill (knives and hammer) and screen hole diameter (0.5 and 0.8 mm). The effects of processing parameters were determined by a factorial experiment varying type of corn (normal and cacahuazintle), lime concentration (0.15 and 0.25% w/w), processing moisture (45 and 48% w/w) and temperature (70, 80 and 90°C). The Statistical Analysis Method (SAS Institute, Inc., 1991) to analyze data, and Duncan means comparisons were used. Significance was defined at $p<0.05$.

RESULTS & DISCUSSION

Evaluation and selection of milling type

The normal corn was denser (Table 1) than the cacahuazintle corn (test weight 75.1 vs. 56.8 kg/hL, respectively). The pearled index of cacahuazintle corn was higher than normal corn mainly because of its higher proportion of floury endosperm and higher amylose content (Trejo-González et al., 1982; Bedolla and Rooney, 1982). Those characteristics are related to grain breakage, grain density and overall dry milling performance (Peplinsky et al., 1992). The chemical composition (Table 1) of the experimental corn kernel was in the range reported by others (Robles et al., 1988; Bedolla et al., 1983).

The mean particle sizes (MPS) of raw corn flour from the two types of corn were compared (Table 2). When the knives mill was used, a finer flour was obtained than with the hammer mill, for normal corn. For both types of corn and mill finer particles were obtained when the 0.5 mm sieve was used, compared with the 0.8 mm sieve. The type mill affected significantly the MPS for cacahuazintle corn contrary to the normal corn. When the hammer mill was used, finer flour was obtained than with the knives mill.

The apparent density of normal corn (Table 2) was affected by the

Table 2—Mean Particle Size (MPS) and Apparent Density (AD) of Normal and Cacahuazintle Corn Raw Flour

Variable[h]	MPS[i] (µm)	AD[i] (kg/L)
NK5	176.14[e]	0.519[b]
NH5	221.01[b]	0.583[ab]
NK8	212.17[c]	0.561[ab]
NH8	284.15[a]	0.609[a]
CK5	162.10[f]	0.477[b]
CH5	158.35[g]	0.470[b]
CK8	194.20[d]	0.469[b]
CH8	176.15[e]	0.480[b]

[a-g]Means with same letter, in same column, not significantly different, ($p > 0.05$).
[h]N= Normal corn, C= Cacahuazintle corn, K= Knives mill, H= Hammer mill, 5= 0.5 mm sieve and 8= 0.8 mm sieve.
[i]Mean values of three repetitions.

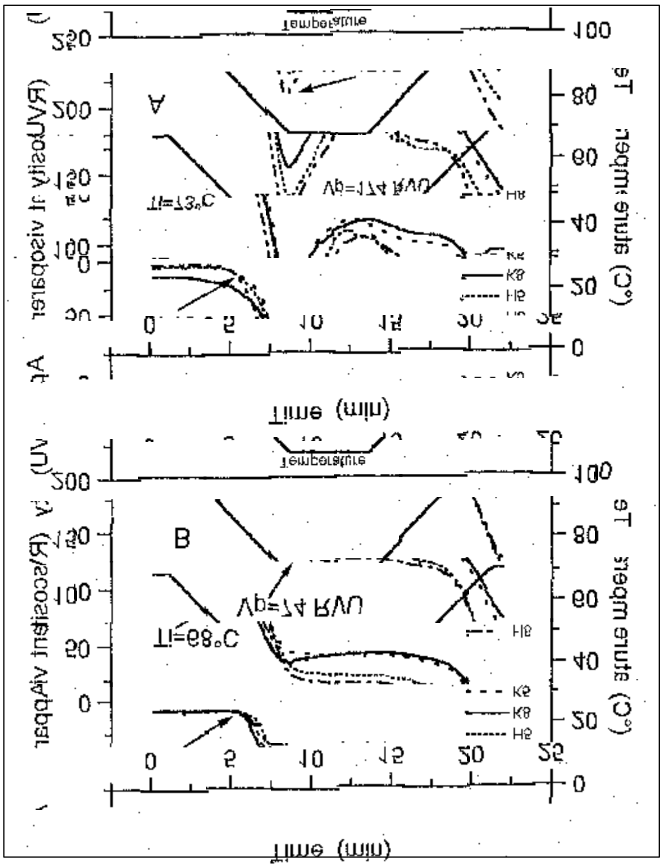

Fig. 1—Apparent viscosity profiles of cacahuazintle (A) and normal (B) corn raw flour processed with different type of mill (H=hammer, K=knives) and sieve size (8=0.8 mm, 5=0.5 mm).

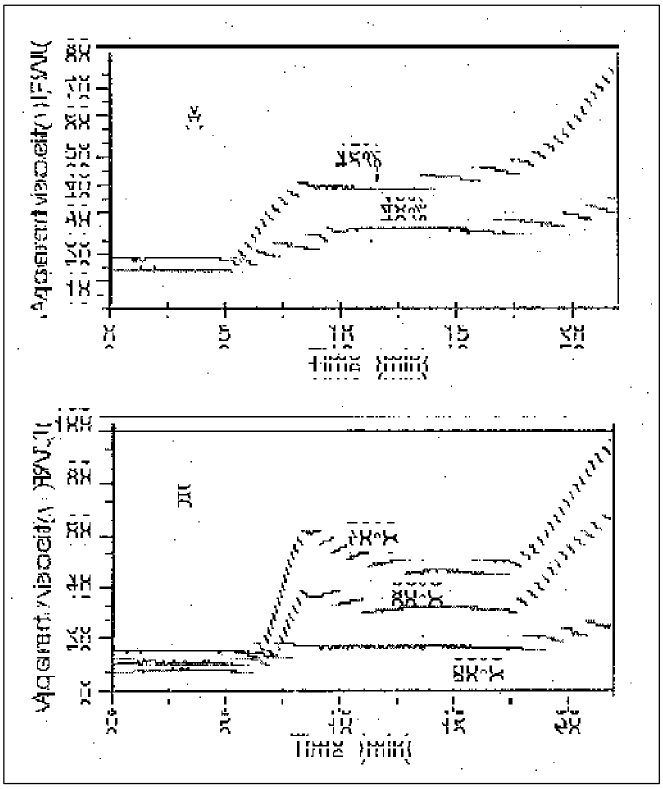

Fig. 2—Effects of processing moisture (A) and temperature (B) on apparent viscosity profiles of instant dry masa flour.

Table 3—Textural characteristics of tortillas of instant corn flour

Variable	Tensile strength[b] (kgf)	Cutting force[e] (kgf)	Rollability[f]
Type of corn			
Normal	0.767[a]	4.164[a]	1.0[b]
Cacahuazintle	0.221[b]	1.724[b]	2.8[a]
Commercial	0.505[c]	3.220[a]	1.0[b]
Type of Mill			
Knives	0.544[a]	3.078[a]	2.1[a]
Hammer	0.444[a]	2.810[a]	1.6[ab]
Commercial	0.505[a]	3.220[a]	1.0[b]
Hole diameter of screen			
0.5 mm	0.499[a]	2.935[a]	2.0[a]
0.8 mm	0.489[a]	2.953[a]	1.8[a]
Commercial	0.505[a]	3.220[a]	1.0[a]

[a-c]Means with same letter, in same column, in each group not significantly different ($p>0.05$).
[d-e]Tested with the Texture Analyzer, TA-XT2, using accessories TA-96 and TA-90, respectively.
[f]Scale: 1, 2, 3, 4, and 5 are breakage degrees of 0, 25, 50, 75, and 100% of the length of the tortilla.

type of mill and sieve. The knives mill produced a flour with lower density than the hammer mill because of the different grinding form. The knives mill cuts and rubs the material producing fine particles and the hammer mill hits and breaks the material producing coarser particles. Also the 0.5 mm sieve flour was lower density than that from the 0.8 mm sieve, probably because of the higher hardness of the normal corn (Table 1) and high resistance in dry milling.

Effects of type of mill and sieve size were compared (Fig. 1) on the apparent viscosity profiles of two types of corn. The initial temperature of gelatinization (Ti) was lower for cacahuazintle raw corn flour than for normal raw corn flour (68°C vs 73°C). The larger starch granules (cacahuazintle corn) gelatinize at lower temperatures than small starch granules (normal corn) (Shuey and Tipples, 1980; Rooney and Serna-Saldívar, 1987). The apparent viscosity peaks (Vp) of the two corn types were affected by type of mill and size of sieve. For the two types of corn the Vp was higher when the hammer mill was used (174 and 74 RVU). That was probably due to the low breakage of starch granules produced by the action of the hammer mill. In general a higher gelatinization peak was observed for the cacahuazintle corn than for the normal corn.

The tensile strength, cutting force and rollability were affected by type of corn (Table 3). The cutting force and rollability values of tortillas made with instant corn flour formed from normal corn were similar to those for tortillas made with commercial instant corn flour. Regarding type of mill and sieve size, the textural quality of tortillas did not show significant differences but values for tortilla obtained with the hammer mill and the 0.8 mm sieve were closer to those values for commercial tortillas. Based on these results, the hammer mill and 0.8 mm sieve were selected as the best performance type of mill. Effects of processing parameters were then evaluated using that type mill.

Evaluation of processing parameters

The corn type affected the color, water absorption capacity and water solubility index of instant corn flour (Table 4). The water absorption capacity of cacahuazintle corn was high, probably because the corn with soft endosperm absorbs more water when gelatinized, than the normal corn with hard endosperm (Bedolla and Rooney, 1982). The cacahuazintle corn showed higher amounts of soluble solids than normal corn. The adhesiveness of masa; tensile strength, cutting force, rollability and puffing of tortillas were affected significantly by corn type (Table 4 and 5). The normal corn showed higher values than the other corn and the hard corn endosperm had produced better tortillas than soft corn endosperm types (González et al., 1991).

The color of instant corn flour and adhesiveness of masas (Table 4) were improved when the lime concentration was increased. Thus the instant corn flour, masa and tortillas showed a yellow color. However, the lime concentration showed adverse effects on water solubility index of instant corn flour and tensile strength of the tortillas.

The tensile strength and cutting force of tortillas decreased when

Table 4—Physicochemical and textural characteristics of instant corn flour and masa

Variable	Color (ΔE)	Water absorption capacity (mL/g)	Water solubility index[d]	Adhesiveness of masa (kg)
Type of corn				
Normal	13.317[a]	0.775[b]	0.086[b]	0.21[b]
Cacahuazintle	12.535[b]	0.919[a]	0.117[a]	0.032[a]
Lime [$Ca(OH)_2$] concentration (%)				
0.15	12.518[b]	0.848[a]	0.106[a]	0.024[b]
0.25	13.334[a]	0.846[a]	0.096[b]	0.029[a]
Processing moisture (%)				
45	12.051[b]	0.825[b]	0.099[a]	0.025[b]
48	13.801[a]	0.869[a]	0.104[a]	0.029[a]
Processing temperature (°C)				
70	10.871[c]	0.829[b]	0.094[b]	0.021[c]
80	12.760[b]	0.816[b]	0.101[ab]	0.025[b]
90	15.146[a]	0.897[a]	0.109[a]	0.033[a]

[a-c]Means with same letter, in same column, in each group not significantly different ($p>0.05$).
[d]Reported in % dry solids per 2.5 g of dry sample.

Table 5—Textural characteristics of tortillas of instant corn flour

Variable	Tensile strength[c] (kgf)	Cutting force[d] (kgf)	Rollability[e]	Puffing[f]
Type of corn				
Normal	1.085[a]	5.085[a]	1.2[b]	2.6[b]
Cacahuazintle	0.598[b]	3.688[b]	1.5[a]	2.9[a]
Lime [$Ca(OH)_2$] concentration (%)				
0.15	0.897[a]	4.498[a]	1.4[a]	2.8[a]
0.25	0.786[b]	4.275[a]	1.3[a]	2.8[a]
Processing moisture (%)				
45	0.906[a]	4.982[a]	1.3[a]	3.0[a]
48	0.777[b]	3.791[b]	1.4[a]	2.6[b]
Processing temperature (°C)				
70	0.936[a]	5.052[a]	1.2[a]	3.0[a]
80	0.886[a]	4.909[a]	1.4[a]	3.0[a]
90	0.702[b]	3.199[b]	1.4[a]	2.3[b]

[a-b]Means with same letter, in same column, in each group not significantly different ($p<0.05$).
[c-d]Tested with Texture Analyzer, TA-XT2, using accessories TA-96 and TA-90, respectively.
[e]Scale: 1, 2, 3, 4, and 5 are breakage degrees of 0, 25, 50,75, and 100% of the length of the tortilla.
[f]Scale: 1 = complete puffing; 2 = medium puffing; and 3 = no puffing.

high moisture and high processing temperature were used (Table 5). The increment of moisture in whole corn flour and processing temperature produced a significant increment of color, water absorption capacity, water absorption index and water solubility index of instant corn flours. In addition, the adhesiveness of masas and puffing were improved (Table 4 and 5).

The most important changes were found when moisture and the extrusion temperature were increased. When processing moisture and temperature increased (Fig. 2), the apparent viscosity of instant corn flour decreased. All such changes were related to the degree of starch gelatinization of the samples. Results confirmed those reported by Mensah-Agyapong and Horner (1992) for lime-treated corn grits processed in a single cook-extruder.

Textural properties of tortillas from instant corn flour using the low shear extrusion process were compared with tortillas formed with commercial instant corn flour used as control. The optimal processing conditions were: normal corn type, 0.15% lime, 48% moisture of whole corn flour and 90°C processing temperature.

CONCLUSIONS

EXPERIMENTAL INSTANT CORN FLOURS WITH DIFFERENT FUNCtional properties and formed with different techniques were influenced by type of corn and processing parameters such as lime concentration, processing moisture and temperature. Tortillas made with instant corn flour of normal corn, processed with hammer mill and 0.8 mm sieve, 0.15% lime, 48% moisture of whole corn flour and 90°C processing temperature, had good performance characteristics with quality similar to tortillas from commercial instant corn flour.

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Ms received 10/28/96; revised 7/1/97; accepted 8/7/97.

One of the authors (A.V.G.) thanks the Consejo Nacional de Ciencia y Tecnología-México (CONACyT), for financial support during studies for the M.S. degree.