Corn Masa and Tortillas from Extruded Instant Corn Flour Containing Hydrocolloids and Lime

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ABSTRACT

Extruded instant corn flour (EICF) samples with hydrocolloids (gums), such as gum arabic, carboxymethylcellulose (CMC), guar and xanthan and with different concentrations of lime (0.1, 0.2 and 0.3% w/w) were prepared by extrusion. The gums were added before or after thermal processing. The dehydration process followed through the weight loss (WL) in masa, the physicochemical (water absorption capacity (WAC) and WL during cooking) characteristics of masa were optimized to give longer dehydration times and tortillas with good textural (rollability, tensile strength and cutting force) properties. The lowest effective moisture diffusion coefficient (D*) was found in masa samples containing 0.2 % (w/w) of lime and 0.5 % (w/w) of the xanthan gum added before extrusion. These masas produce tortillas with optimum textural characteristics and highest yields.

Key Words: moisture diffusion, hydrocolloids, extrusion, tortilla, corn masa

INTRODUCTION

TORTILLA CAN BE PRODUCED FROM FRESH MASA using traditional nixtamal made of whole corn grains cooked with water and lime and ground, or instant corn flour (ICF) which is dehydrated masa. The ICF has become useful because it does not require the intensive and tedious work of the traditional process to provide tortillas and it can be stored long times without affecting its quality (Arámbula, 1994). The moisture concentration in fresh corn masa for tortillas is in the range of 48-52% (w/w). Nevertheless, fresh masa is highly susceptible to lose moisture which makes its texture hard and therefore difficult to shape into round flat form.

Good quality corn tortillas are soft and can be rolled into "taco" form without damage. The textural characteristics of tortillas are related to the binding forms and to the amount of water contained. A dehydrated corn masa produces hard and breakable tortillas. Thus, retention of water in masa and tortilla is important since excessive water loss makes an unacceptable product.

Commercially, the ICFs are formulated with gums (water soluble polysacharides of high molecular weight) and preservatives to retain water and improve physicochemical properties and textural characteristics. The gums increase viscosity of masa and during thermal processes compete with water retarding the degree of starch gelatinization (Bell, 1990; Christianson, 1982). Also, during cooling, the gums inhibit retrogradation of gelatinized starch granules increasing the flexibility of tortillas (Yau et al., 1994). The degree of starch gelatinization during thermal processing changes the ability of ICF to absorb and retain water. This ability is important during the rehydration of ICF to form masa and can be associated with structural changes in masa and textural properties of tortillas.

The importance of adding lime in the traditional nixtamalization process, has been investigated (Trejo-González et al., 1982; Rodríguez et al.,1996; González-Hernández et al., 1997). However, the effects of calcium in the process are not completely understood. Lime (calcium hidroxide) imparts desirable functional properties to the tortillas (color, flavor, texture and shelf life) and is important for the prevention of pellagra and osteoporosis (González-Hernández et al., 1997). Arámbula (1994) found that the optimum level for lime in EICF was ≈0.15-0.2% (w/w). In corn masas where hydrocolloids are included they interact with components of corn (starch, proteins and lipids) and lime producing different effects depending on the type and concentrations. The gums we evaluated had been used in bread production and had high water retention ability, gave improvements in the quality of bread loaf (Cristianson et al., 1982) and improved handling properties (Ward and Andon, 1993).

The main objective of our work was to evaluate the effects of various commercial gums and lime, added before or after processing, on the moisture content and dehydration process in masa prepared using a specially designed extruder. The dehydration rates were related with the physicochemical properties of EICF and with the textural characteristics and tortilla yield. The WAC in EICF, the D*, in fresh masa as well as yield and textural characteristics (rollability, tensile strength and cutting force) were used to optimize processing conditions to produce masa for tortilla production.

MATERIALS & METHODS

Commercial white corn samples (ASPROS AS-910), powdered hydrated lime (El Topo, Monterrey, N.L. México) and hydrocolloids were used to produce the flour samples. Four types of hydrocolloids were used: guar, CMC (Química Hércules S.A. de C. V., México), xanthan and gum arabic (Dermet de México, S.A. de C. V). Moisture content was determined according to method 44-19, AACC (1983). WAC of EICF was evaluated using the procedure described by Bedolla (1983).

Production of extruded instant corn flour

A custom made low shear extruder (Talleres Garcia, S.A., Monterrey, N.L., México) specially designed to produce corn masa and ICF (U.S. patent, Martínez et al., 1996), was used to prepare the ICF samples. Whole corn kernels were ground with a mill (Pulvex-200, sieve 0.8 mm, Pulvex, S.A. de C.V., México, D.F.) using a hammer head. Samples containing 1 kg of milled corn, different concentrations of lime, hydrocolloids at 0.5% (w/w) and water (730 mL/kg milled corn) were mixed with a domestic blender (Kitchen Aid, K5SS, St. Joseph MI). The hydrocolloids concentration was fixed at 0.5% (w/w) because this had been found to be the optimum for tortilla quality. The samples were extruded at 25 rpm with 1.3 min residence time to produce fresh masa in pellet form. The corn masa was dehydrated in an experimental IR tunnel dryer (Talleres Garcia,S.A., Monterrey, N.L., México), to provide pellets with 8-10% moisture.

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The dry masa was ground (Pulvex-200, sieve 0.8 mm, hammer head) to provide the ICF from which tortillas were elaborated. The hydrocolloids were added before or after samples were processed by extrusion. The lime was added before extrusion in all cases.

Preparation of masa, tortillas and yield

EICF (300g) was rehydrated with enough water to provide fresh masa with proper 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 then rounded and shaped in the form of flat discs using a small roll tortilla machine (Casa González, México, D.F.). The masa discs were cooked on a hot plate at about 290±10ºC for 27s on one side, 30s on the opposite side, and then turned back to the first side and cooked until puffing. Dimensions of the tortillas were of 1.2±0.1 mm in thickness, 12.5±0.2 cm diameter and a weight of 18±0.5g. Masa samples consisting of 1 kg of EICF with the proper amount of water were prepared to form tortillas and the tortilla yield was calculated as kg of tortillas produced/kg of EICF.

Weight loss of tortilla during cooking

The WL was determined weighing a tortilla before and after cooking using a triple beam balance (OHAUS, Florham Park, NJ, cap. 2610g) and reported as percentage according to the formula: [(wt of raw tortilla - wt of cooked tortilla)/(wt of raw tortilla)] × 100.

Rollability of tortillas

The rollability of tortillas was determined according to the procedure described by Bedolla, (1983) using tortillas that were kept for 30 min at room temperature after being cooked. The whole tortilla was rolled around a glass rod of 2 cm diameter and the breakage degree was determined using a perception 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.

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 with probet form cut from 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/s until the tortilla broke. Two tortillas of each treatment were evaluated 30 min after they were made. Before these measurements, the tortillas were kept at room temperature. 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/s until the tortilla was cut. The tensile strength and cutting force were expressed as the peak force (g_f) required to break or cut the strip.

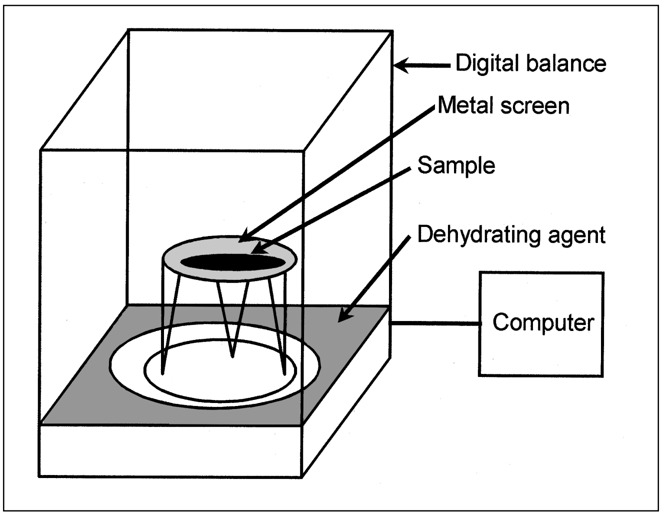

Fig. 1—Schematic arrangement of system to measure weight loss (WL) of masa.

Dehydration kinetics and effective moisture diffusion coefficient

Dehydration curves of masa samples were derived using the following procedure: masa samples of 1.7±0.01g, obtained from EICF, were shaped in a thin disk form 1.27±0.01 mm thick and 37.25±0.1 mm diameter. The sample was placed onto a structure that contained a metal screen in the chamber of a digital balance (Fig. 1). A dehydrating agent $CaCO_3$ was placed into the closed chamber to remove excess moisture. The WL due to dehydration was computer monitored as a function of time until a constant weight was reached.

D* was determined by a fast method based on a phenomenological analysis of the dehydration process at room temperature.

The method to determine D* assumed that the sample had a shape such that its lateral dimensions were much larger than the thickness and the water loss (ΔWexp) due to dehydration must occur by evaporation through both surfaces and was expressed by:

$$\Delta W_{exp} = 2\mu g S \int_0^t j dt \quad (1)$$

where μ = the mass of the water molecule, g = the gravitational acceleration, S = the surface area, j = the evaporation rate per unit surface, and t = the measuring time.

Under this assumption:

$$(d\Delta W_{exp})/dt = 2\mu g S j \quad (2)$$

The evaporation rate density j in the experimental quasi-equilibrium conditions (slow evaporation) was equal to the diffusion water flux from inside to the sample surface, i.e.:

$$j = -D(dn/dx) \quad (3)$$

where D was the diffusion coefficient.

Under the above quasi-equilibrium conditions no storing of free water inside the sample moved exist. Thus j did not depend on "x". If we assume that D at any given time is constant, the effective diffusion coefficient D = D* can be defined by:

$$D^*(dn/dx) = \text{constant} \quad (4)$$

so that at any time, n(x) is a linear function which could be estimated as:

$$|dn/dx| = 2n_0/l \quad (5)$$

n_0 being the water concentration in the sample and l the sample thickness. Here we also assumed that the moisture concentration in the ambient atmosphere was negligible compared to n_0. If this is not the case, we simply introduce the difference between the n_0 and the ambient moisture concentration in Eq (5); the corresponding correction is entered in the final expression.

Having introduced Eq (5) and Eq (4) into Eq (2), we obtain:

$$d\Delta W_{exp}/dt = [4D^*\mu g S n_0(t)]/l \quad (6)$$

Since

$$[\mu g n_0(t)/2] = W(t)/Sl \quad (7)$$

a final expression for D* is obtained:

$$D^* = [l^2 d\Delta W_{exp}(t)]/8W(t)dt \quad (8)$$

The residual moisture concentration (RMC) at a given dehydration time (*t*) was determined by subtracting the WL at the time *t* from the total WL and then dividing that difference by the total weight of sample after dehydration. By our definition, the residual moisture concentration in the samples is not the absolute water content, but rather it is the moisture concentration which has the zero reference as the equilibrium moisture concentration at room temperature (25ºC).

Experimental design

A factorial arrangement was used to select the best quality tortilla, evaluating lime concentration (0.1, 0.2 and 0.3% w/w), type of hydrocolloids (gum arabic, CMC, guar and xanthan) and the stage at which the hydrocolloids were added (before or after processing). The Statistical Analysis Method (SAS Institute, Inc., 1989), and Duncan´s means comparisons (P<0.05) were used to analyze the data.

RESULTS & DISCUSSION

TYPICAL EXPERIMENTAL DEHYDRATION CURVES FOR MASA prepared from ICF obtained using the traditional nixtamalization process were compared (Fig. 2) with those for liquid water measured under the same conditions. The dehydration rate, moisture lost per unit time and area, for liquid water was independent of time and equalled 7.6×10^{-6} g/s-cm^2. For the masa sample, the dehydration rate change with time, becoming lower as time increased, becoming almost zero after reaching the equilibrium weight at about 7h. According to the dehydration kinetic theory, the dehydration curve for the masa sample could be divided into three regions, A, B and C. In region A the dehydration rate was the highest (almost constant), slightly dependent on time and its value was not much less than that for liquid water. In region B the dehydration rate diminished quickly with time (variable rate) and in region C it remained basically unchanged (almost zero). These three regions were related to the different bonding states of water in masa and foodstuffs in general. Unbound or free water diffuses out first at constant and high rates (region A), followed by weakly bound water, diffusing at lower rates (region B) and finally at very low rates the diffusion of strongly bound water occurs (region C). In this latter region, we were probably observing the loss of the last few molecular layers of water adsorbed on the surface of starch granules.

Experimental dehydration curves were also compared (Fig. 3) for masa samples obtained from EICF containing 0.2% (w/w) of lime and 0.5% (w/w) of four different commercial gums. For comparison, the dehydration curve for masa prepared from ICF obtained using the traditional nixtamalization process is also shown. The gums were added to the raw mixture before being processed in the extruder to form the ICF. Results showed that the dehydration rates for masa samples containing gums were lower than those in the masa prepared using nixtamalized corn flour. Thus, the amount of moisture lost before reaching equilibrium weight was less in the extruded masas containing gums. For all samples containing gums the equilibrium weight value was about the same, although the dehydration rates depended on the kind of gum. The insert (Fig. 3) shows the percentage of weight loss (ΔW) obtained from dehydration curves after 2h dehydration. The ΔW value for masa prepared from EICF using the same parameters but with no gums was denoted by the letter "S". After 2h dehydration, the masa sample with xanthan gum had the smallest water loss percentage. The rate of dehydration of masas during the first few hours after preparation was of special interest because in general the tortillas are prepared during that time. For nixtamalized masa (N) the ΔW was the highest (about 33% after 2h dehydration). This higher value was probably due to the fact that most of the natural gums present in the corn skin were dissolved and washed away as part of the nejayote during the wet cooking of corn to form nixtamal.

Dehydration curves were compared (Fig. 4) for masa samples containing 0.2% (w/w) of lime and 0.5% (w/w) of different types of gums. The gums were added to the corn flour after processing in the extruder. All masa samples with gums dehydrated at very similar rates during the first stages, that is, in the water free region. In this case, the equilibrium weight depended on the kind of gum added. Xanthan and Guar gums resulted in the least water loss.

According to Eq (8), D* could be obtained from the dehydration curves and depends on the dehydration time and therefore on the moisture concentration. It has been shown that, in a porous material, such as the masa, D* has a maximum at about 10% (w/w) of moisture concentration (Vagenas and Karathanos, 1991).

The calculated D* was compared (Fig. 5), for the time corresponding to 10% (w/w) of RMC for masas prepared from EICF having 0.1, 0.2 and 0.3% (w/w) of lime and no added gums. The values are averages of two independent measurements and trends did not

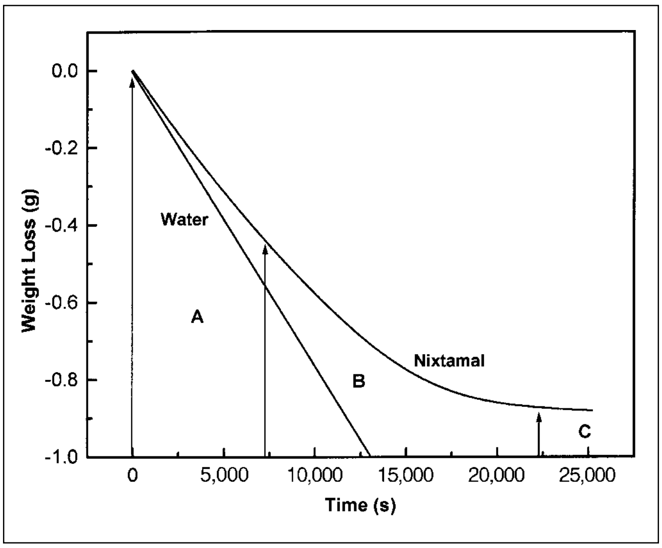

Fig. 2—Typical room temperature (25°C) dehydration curve for liquid water and nixtamal masa from instant flour.

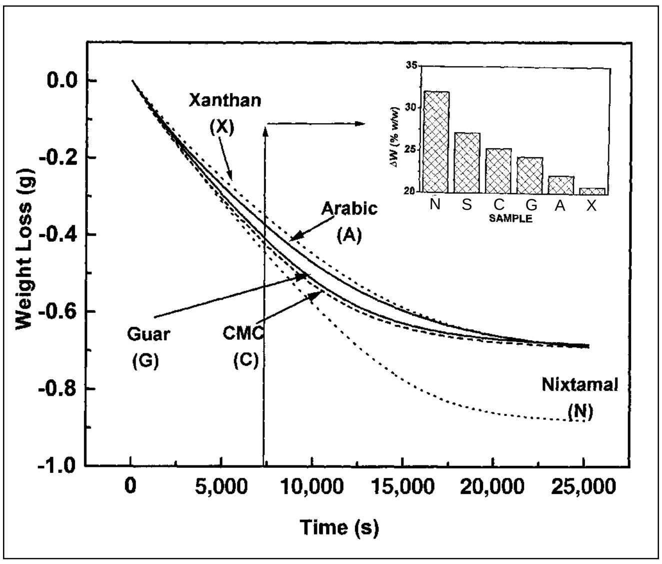

Fig. 3—Dehydration curves for masa prepared from extruded instant corn flour (EICF) with gums added before processing. The insert compares the percentage of water loss (ΔW) after 2h of dehydration.

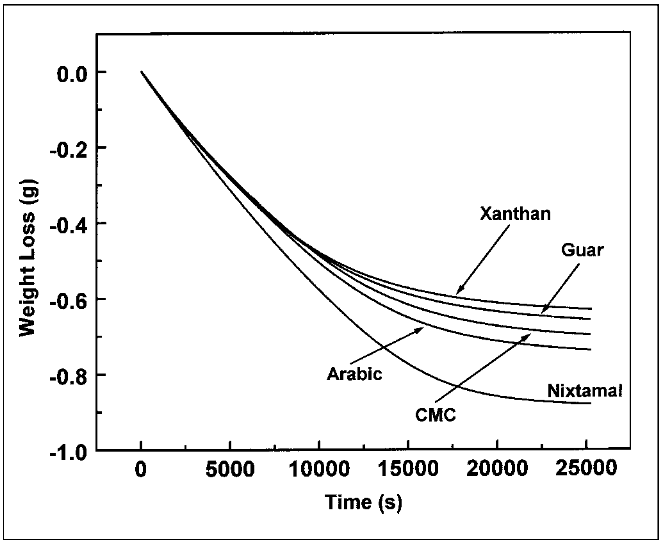

Fig. 4—Dehydration curves for corn masa prepared from extruded instant corn flour (EICF) with gums added after processing.

change for moisture concentrations over a wide range. The lowest value of D* was obtained when 0.2% of lime concentration was used. Studies by Rodríguez et al., (1995) have shown that some physical properties of tortillas, such as heat conduction, cohesiveness and adhesiveness were optimum for lime concentration of about 0.25% (w/w). The explanation of Rodríguez et al., (1995) was that lime fully interacted with the hydroxyl groups of starch molecules until it reached a maximum at about 0.2-0.25% (w/w). For higher concentrations the ions did not react and they formed calcium complexes which acted as thermal barriers and diminished the mechanical properties of the tortillas.

The calculated D* was compared (Fig. 6), for masa samples prepared from EICF with 0.2% (w/w) lime and 0.5 % (w/w) of gums added before and after processing. The values are averages of two independent measurements and all samples showed smaller D* values when the gums were added before than after extrusion. The smallest D* value was for the xanthan gum. This was the same as observed for moisture concentrations over a wide range. The longer dehydration times in samples for which the additives were incorporated before extrusion were expected because additives had better thermal conditions and longer times to interact or react with others components of corn (starch, proteins and lipids).

The WAC in EICF with 0.2% (w/w) of lime, the WL of tortilla during cooking and the tortilla yield were compared (Fig. 7). The experiments were done in samples containing the 4 types of gums added before extrusion. The reported values were averages of two independent measurements. Results showed that the highest tortilla

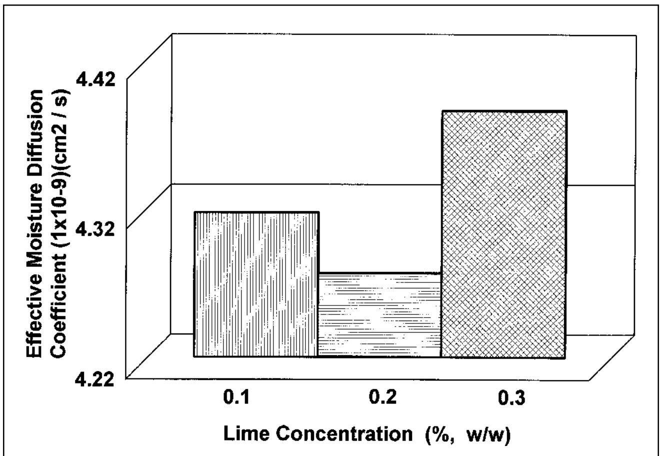

Fig. 5—Effective moisture diffusion coefficient, D*, for masa prepared from extruded instant corn flour (EICF) containing three different amounts of lime and no gums added.

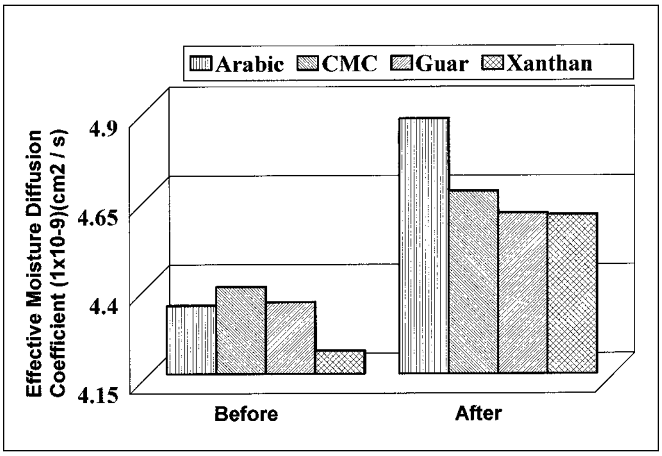

Fig. 6—Effective moisture diffusion coefficient, D*, for masa prepared from extruded instant corn flour (EICF) containing 0.2% of lime and with gums added before or after processing.

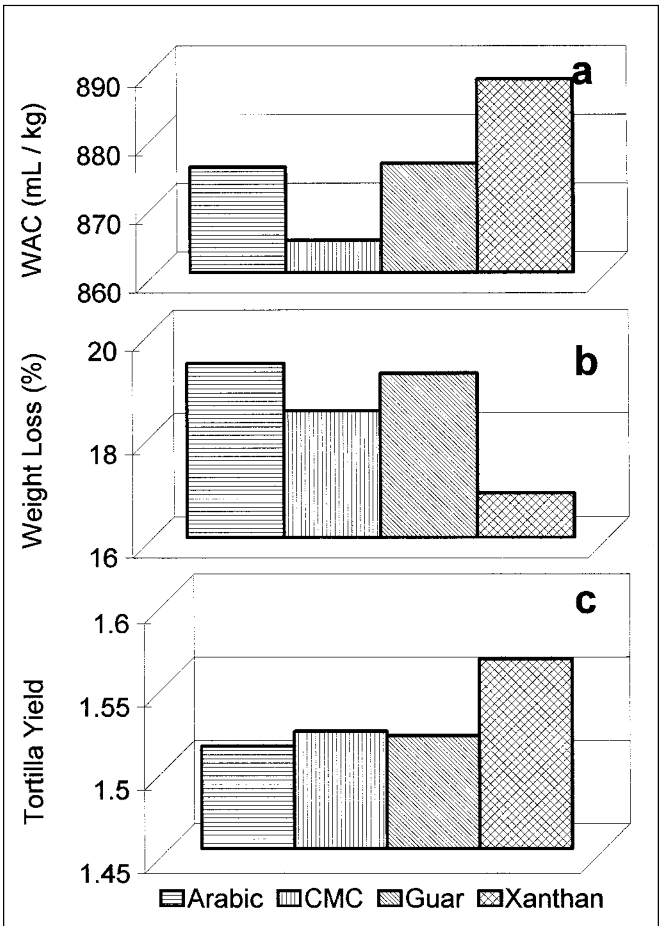

Fig. 7—Water absorption capacity (WAC) for extruded instant corn flour (a), weight loss during tortilla cooking (b) and tortilla yield from extruded instant corn flour with 0.2% of lime and different gums added before processing.

Table 1—Textural characteristics of tortilla produced from extruded instant corn flour (EICF) containing 0.2% lime with gums added before or after processing

	Before			After		
Gum	Cutting Force (g)	Tensile Strength[d] (g)	Rollability[e]	Cutting Force (g)	Tensile Strength[d] (g)	Rollability[e]
Arabic	1140.83[a]	162.50[a]	1.56[b]	1210.00[a]	203.08[a]	1.62[a]
CMC	1107.67[a]	156.00[a]	1.62[b]	1221.08[a]	180.75[a]	1.69[a]
Guar	1117.75[a]	176.50[a]	2.23[a]	1129.58[a]	196.83[a]	1.22[a]
Xanthan	835.42[b]	123.75[b]	1.33[b]	938.00[b]	118.00[b]	1.66[b]

[a,b]Means with same letter, in same column, not significantly different ($p > 0.05$).
[c,d]Tested with Texture Analyser, 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.

yield was obtained for masas containing xanthan gum. This was the result of higher WAC and lower WL. The lower yields observed in masa containing other gums, was the result of lower WAC and higher WL. The lower WL in tortillas with xanthan gums agreed with dehydration of masas showing the lowest rates for those containing xanthan. A high tortilla yield has important commercial benefits because water is almost half the tortilla weight.

To commercialize tortillas successfully, a high yield must be accompanied by high product quality. Some textural characteristics of tortillas prepared with the 4 types of gums added before and after extrusion were compared (Table 1). The ideal textural parameters in a tortilla are: low tensile strength and cutting force (151.8 and 880.7 g_f, respectively, Arámbula, 1994), as well as good rollability. In general, the textural characteristics of tortillas were better when gums were added before extrusion. These corresponded to masas and tortillas with higher water retention. According to this criteria, the masa and tortillas prepared from EICF with xanthan gum added before extrusion would result in the best quality. For other food products, Ward and Andon (1993) have shown that the performance of gums may be affected by pH and other chemical factors.

CONCLUSIONS

MASAS AND TORTILLAS FROM CORN FLOURS CONTAINING DIFferent types of commercial gums and various amounts of lime were produced using a specially designed extruder. The gums were added before or after extrusion. Using room temperature dehydration curves, masa with 0.2% (w/w) of lime and with xanthan gum added before extrusion process retained the highest amounts of moisture. Tortillas made from this masa showed the highest yields and the best textural characteristics.

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