Influence of Monoglycerides on the Textural Shelf Life and Dough Rheology of Corn Tortillas[1]

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ABSTRACT

The addition of monoglycerides (MGs) (monomyristin, monopalmitin, and monostearin) to corn tortillas was tested for their effects in delaying staling. Two levels (0.2% and 0.4%) of each MG were studied with storage at 4° C for zero, one, two, and three days and storage at −20° C for 30 days. A sensory panel determined changes in rollability, firmness, dryness, and flavor. A method was developed by using the Ag Canada multiblade shear cell attached to an Instron universal testing machine (model 1122) to determine firmness. The addition of either level of the MG preparations gave tortillas that were softer (by Instron and sensory firmness), more rollable, and less dry than the control ($P < 0.05$) during storage. Few significant differences were noted among the different MGs or levels.

A major problem facing food manufacturers and consumers is staling of cereal-based food products such as bread or tortillas. To delay staling, most food companies incorporate monoglycerides (MGs) in breads. Studies by Mikus et al (1946) showed that MGs form complexes with amylose. Krog (1977) and others (Krog and Jensen 1970, Lagendijk and Pennings 1970, Russell 1983) found that there is a high correlation between amylose complex formation and the crumb-softening effect of MGs in bread products. Knightly (1973) and Lagendijk and Pennings (1970) discovered that saturated MGs are more effective than unsaturated MGs in complexing with amylose, with monopalmitin (MP) being the most effective. However, Elaisson and Krog (1985) found monomyristin (MM) to have the best complex-forming capability of the MGs studied (monolaurin, monopalmitin [MP], monostearin [MS], monoelaidin, monolein, and monolinolein). Batres and White (1986) demonstrated that MGs also complex with the amylopectin fraction, with MP exhibiting the greatest complexing ability. Hence, MGs may help to delay staling by complexing with both the amylose and amylopectin fractions.

Furthermore, commercially prepared surfactants and MGs are used by food manufacturers to improve the dough strength, volume, and texture of baked goods. Researchers (Knightly 1973, Hoseney et al 1970, Chung 1986) found surfactants to be effective in increasing dough strength and mixing tolerance, extensibility, and water absorption. Pisesookbonterng and D'Appolonia (1983a) postulated that binding of surfactants (sodium stearoyl lactylate, polysorbate 60) to protein, which results in dough strengthening, might have an influence on the denaturation or configuration modification of the gluten in the bread crumb, particularly after four days of storage. Thus, the use of surfactants could help to delay staling because of the effect on protein structure as well as from the effect on starch.

Although MGs have proved successful in delaying the staling of starch in bread products, little work has been done to ascertain their effectiveness in delaying staling in tortilla (wheat and corn) products. Currently, food companies add gums to enhance water retention and improve rollability of wheat tortillas (Gorton 1984). To improve shelf life, some manufacturers add preservatives such as calcium propionate or potassium sorbate (Luke and Andres 1981). Commercially prepared surfactants or glycerin are sometimes added to wheat tortillas, whereas no surfactants are currently added to corn tortillas. Bedolla (1983) found that the use of MGs (Dur-Em 207, Durkee) improved the texture of corn tortillas. From experiments using the Instron universal testing machine, Bedolla (1983) reported that MGs cause a decrease in firmness compared with a control without MGs.

At present, most package directions suggest that wheat and corn tortillas be stored at either refrigerator or freezer temperatures. After only short storage periods under these conditions, the products become firm, extremely dry, and less easily rollable. Because of the relatively short shelf life of corn tortillas, better ways to delay staling and to improve textural properties need to be investigated. Incorporation of MGs into tortillas could delay staling and improve product quality.

The objectives of this study were to 1) characterize the textural properties of masa harina (corn) dough and the shelf life (staling rate) of cooked corn tortillas; 2) develop methods to evaluate the textural properties of corn tortillas, including machinability of the masa dough, and rate of firming of the cooked tortillas; and 3) evaluate the effect of various purified MGs (MM, MP, MS) on the staling of corn tortillas.

MATERIALS AND METHODS

Method for Making Tortillas

Corn tortillas were made from commercially available masa harina flour (50-lb bag; Quaker Oats, Inc., Barrington, IL) by using a procedure suggested by Bedolla (1983). Pure MGs in a powder form (MM, MP, and MS) were purchased from Sigma Chemical Company (St. Louis, MO).

To make the tortillas, 200 g of masa harina flour was weighed into a stainless steel mixing bowl. Commercial preparations of MGs were added and mixed at speed no. 2 of a KitchenAid mixer for 10 min. Tap water (216 g at 70° C) was added to the flour and then mixed at speed no. 2 for 1.5 min. The dough was rolled into 20-g balls and covered with a cloth towel. Each dough ball was flattened with a Tortilladora tortilla press (Atlas, San Francisco, CA), heated on a griddle (380° F) for 1 min, turned and heated for 40 sec, and then flipped back to be heated for 20 sec. The tortillas were cooled for 10 min on a rack while covered with a paper towel and then stored in moisture-proof plastic bags at 4° C or −20° C. To reheat, the tortillas were taken directly from storage, placed in a plastic cooking bag, sealed with a twist tie, and baked at 350° F for 3 min (refrigerated samples) or for 5 min (frozen samples). The tortillas were then cooled to room temperature (25° C) for sensory evaluation and Instron tests.

Tests for Physical and Chemical Properties of the Flour

Moisture and crude protein were determined by using AACC methods 44-19 and 46-12, respectively (AACC 1983). Two different water absorption indexes (WAI and WAIS), pH, and particle size distribution were measured using methods described by Bedolla (1983). For pH determination, 10 g (db) of flour was placed in a beaker that contained 100 ml of 25° C distilled water that had been recently boiled. The mixture was agitated with a rod every 5 min for a total of 20 min. The pH was determined with a Fisher Accumet pH meter, model 230A, which had been calibrated

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against a buffer solution of pH = 7.0. To measure particle size distribution, one 100-g flour sample was placed in a stack of five U.S. standard testing sieves (no. 25 = 710 μm; no. 60 = 250 μm; no. 70 = 210 μm; no. 80 = 170 μm; no. 100 = 149 μm). The stack of sieves was placed on a Rotap-Sieve shaker for exactly 3 min, and the overs were weighed and expressed as percent overs based on a total recovery of 97%.

A method of Williams et al (1970) was used to determine soluble amylose. Amylograph viscosity of the flour was measured by using AACC method 22-10 (AACC 1983). Starch content was determined by using the AACC method 76-11 (AACC 1983) with modifications. To ensure complete gelatinization of the starch, the suspension was heated at 121°C for 3.0 hr rather than at 135°C for 1.0 hr. In addition, to measure the glucose concentration, 5.0 ml of peroxidase-glucose oxidase solution was added to each tube of sample and standard. All tubes were incubated at room temperature for 45 min in the dark, and the absorbance of each sample was read in a Spectronic 20 spectrophotometer (Bausch and Lomb, Inc.) at 435 nm.

Storage Study

Tortillas containing no MGs (control) and tortillas containing one of each MG (0.2% or 0.4% MM, MP, or MS) were compared during refrigerator (4°C) storage (0, 24, 48, or 72 hr) and freezer (−20°C) storage (30 days). Monoglyceride percentages were based on flour weights. All treatment combinations were prepared and stored four separate times for a total of four replications. All data were analyzed by analysis of variance (ANOVA).

Sensory Evaluation

Ten to 12 trained sensory panel members measured changes in rollability, firmness, and dryness of tortillas during storage. To measure rollability, panelists were asked to loosely fold each tortilla, bringing just the top edges together, and hold for 5 sec. The rollability was measured by the degree to which each tortilla cracked. The tortillas were presented in random order and the characteristics were measured on seven-point scales. Panelists were asked to comment informally on the presence and nature of any off-flavors. All sets of panel evaluations were repeated four times, once for each replication.

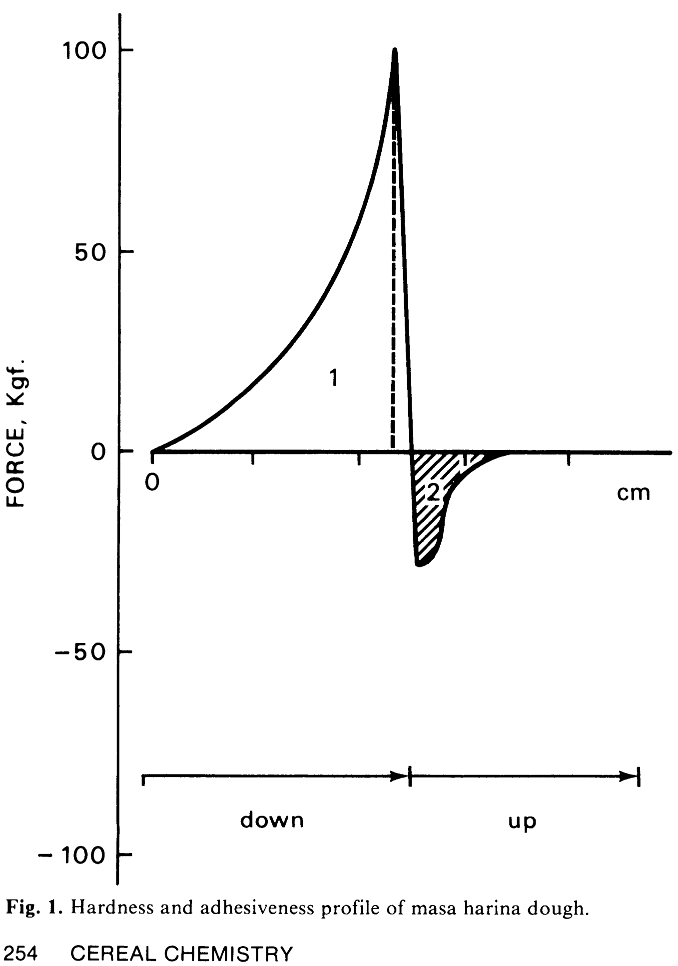

Fig. 1. Hardness and adhesiveness profile of masa harina dough.

Instrumental Evaluation

The Instron universal testing machine (model 1122) equipped with the Ag Canada multiblade shear cell was used as an instrumental measure of texture (cutting/shear) of the tortillas. The crosshead and chart speeds both were set at 200 mm/min. The measure was expressed as peak force (kg). Four tortillas from each treatment were measured each day, and the results were averaged. These measurements were repeated for each of the four replications.

In addition, the Instron universal testing machine with a plunger (66.5 cm^2) attachment was used as an objective measure of the masa harina doughs containing MGs (0.2% and 0.4% MM, MP, MS) and of the control. According to De Padua and Padua Maroun-Ciepe (1984), this method measures adhesiveness and firmness of the doughs. The measure was used as an indication of the effect of the different MGs on machinability of the dough. The crosshead speed was set at 100 mm/min, with the chart speed set at 200 mm/min. Masa harina dough weighing 200 g was shaped into a 3 cm (thick) × 7 cm (length) × 8 cm (width) cube and was compressed with the Instron to 20% of its thickness. After 1 min, the plunger was removed from the dough. Two peaks resulted from the test (Fig. 1). Both peak height (cm) and area (cm^2) were measured for peak 1, with only peak height (cm) measured on peak 2. Peak heights were expressed as kilogram force. Three replications of each dough were evaluated on three different days. Data were analyzed by ANOVA.

RESULTS AND DISCUSSION

Physical and Chemical Properties of the Flour

Measurements of the physical and chemical properties of the flour reported are the mean of at least four separate analyses. The moisture content of the masa harina flour (9.8%) was slightly lower than moisture contents of masa harina flours measured by other researchers (Adams 1975, Bedolla 1983, Bedolla et al 1983, Bedolla and Rooney 1984), which ranged from 10.6 to 12.0%. The protein, starch, and amylose contents of the flour were 8.7, 76.6, and 21.0%, respectively, and were similar to those of masa harina flours measured by other researchers (Adams 1975, Bedolla 1983, Bedolla et al 1983, Bedolla and Rooney 1984). The pH (7.7) of the flour was slightly higher than the values found by Bedolla (1983) for American flours, which ranged from 6.8 to 7.5.

Two different water absorption indexes were measured. The WAI (water absorption by centrifugation) was determined by centrifugation of a flour and water suspension, and the value was 3.11 expressed as grams of gel per gram of dry flour. By this measure, it was determined how much water could be absorbed by the dry flour. The WAI value obtained was lower than that found for flours measured by Bedolla (1983) (4.28 g H_2O/g dry flour). In an earlier study, Bedolla (1983) found that WAI was significantly correlated with pH, protein content, extent of starch gelatinization, and particle size on three different sieves (nos. 60, 70, and 80). Each of these properties partly accounts for the water absorption of masa harina flour. The WAIS (water absorption by subjective measure) of 1.08 g H_2O/g flour was determined subjectively and corresponded with the optimum amount of water needed to make a masa harina dough with an acceptable consistency. The WAIS value was similar to that reported by Bedolla (1983) for masa flour (1.02 g H_2O at 70°C/g dry flour). The higher the WAIS value, the higher the yield of tortillas; however, a high moisture content results in a reduced shelf life (Bedolla and Rooney 1984). By Instron measure, Bedolla et al (1983) confirmed that tortilla texture (expressed either as total area under the curve or peak height) is related to masa moisture content. They reported that an increased moisture content in the masa produced tortillas with a softer texture.

The particle size distribution of the masa harina flour resulted in the majority of the flour particles being retained on nos. 60 and 70 sieves; 41 and 44%, respectively. This was similar to the particle size distribution found by Bedolla (1983) for a number of American masa harina flours. According to Bedolla (1983), this measure might be useful in predicting tortilla texture, rollability, crispness, and absorption.

Tortilla Storage Study—Instron Texture Measurements

The Instron results of the storage test in which tortillas containing pure MGs were compared are shown in Table I. Few significant differences in peak size were seen between treatments. However, on day 0, the control was significantly ($P < 0.05$) firmer than all the other products except for the tortilla containing 0.2% MP, which also was significantly firmer than the tortilla containing 0.4% MS. On days 1 through 3, the control tended to be firmer, but the mean results were significantly different ($P < 0.05$) in only a few cases (tortillas containing 0.2 and 0.4% MS on day 1).

Even so, the tendency throughout storage at 4°C was for the firmness of the samples to increase and for the differences between the treatments to decrease. The tortillas containing MS were generally the softest, especially at the beginning of refrigerator storage. After storage at −20°C, the tortillas containing 0.2% MP, 0.2% MM, and 0.4% MS scored significantly lower than the control ($P < 0.05$), with all MG treatments generally being softer than the control. Bedolla (1983) also found that the use of a mixture of MGs (Dur-Em 207, Durkee) also reduced the firmness of tortillas as measured by the Instron.

Sensory Evaluation

Firmness. On day 0, the control was significantly ($P < 0.05$) firmer than all tortillas that contained MGs (Table II). The tortilla with 0.2% MP was significantly ($P <$ O.05) firmer than tortillas containing 0.4% MM, 0.4% MP, and 0.4% MS. The differences among the treatments were not noted after one day of storage. On day 3, the tortilla containing MM tended to be the softest, but was not significantly different. Overall, the tortillas with MGs were generally softer than the control throughout storage at 4°C.

After frozen storage, all tortillas containing MGs except the tortilla with 0.2% MS were significantly ($P < 0.05$) softer than the control. Both tortillas containing MM (0.2% and 0.4%) were softer ($P < 0.05$) than the tortilla containing 0.2% MS and tended to be softer than the other treatments.

Rollability. On day 0, four of the treatments were more rollable ($P < 0.05$) than the control (Table II). Throughout the refrigerator study, the tortilla with 0.2% MM was the most rollable, although not always significantly. All tortillas with MGs had a tendency to be more rollable than the control.

After freezer storage, there were no significant ($P < 0.05$) differences among treatments, although the tortilla containing 0.2% MS had the highest score, followed closely by tortillas containing 0.2 and 0.4% MM. In general, during both refrigerator and freezer storage, tortillas containing MM (0.2%, 0.4%) and MS (0.2%) were the most rollable.

Dryness. On day 0, all tortillas that contained MGs were significantly moister ($P < 0.05$) than the control (Table II). Although not always significant, the control continued to be the driest throughout storage. On day 0, all tortillas containing 0.4% MG tended to be more moist than those containing 0.2% MG. By days 2 and 3, the tortilla containing 0.4% MM was generally the most moist.

After freezer storage, only the tortilla containing 0.2% MM was significantly moister ($P < 0.05$) than the control. However, all the tortillas containing MGs tended to be better after freezer storage than the control.

Off-flavor. Panelists were asked to record informal comments regarding the nature and extent of any off-flavors. Several panelists reported a "slight" off-flavor. The panelists were allowed to informally sample commercially sold corn tortillas, which all agreed were very poor in flavor and texture compared with the ones prepared for this study.

Although the differences were not always significant, the effects of the different MGs on storage of the tortillas are interesting. The MS generally had more effect than the other MGs at the beginning of storage, whereas MM and (somewhat less) MP tended to be the most effective after longer storage periods.

Current staling theories for wheat bread suggest that amylose completely recrystallizes during cooling of bread after baking,

TABLE I
Instron Values for Fresh and Stored Tortillas[a]

Monoglyceride Added	Day[b] 0	1	2	3	30
Control	33.6 c	32.0 b	34.4 a	34.0 a	38.4 b
Monomyristin					
0.2%	28.4 ab	28.4 ab	31.2 a	29.6 a	29.2 a
0.4%	26.8 ab	26.0 ab	28.8 a	28.8 a	32.0 ab
Monopalmitin					
0.2%	30.0 bc	26.8 ab	27.2 a	31.2 a	29.2 a
0.4%	25.6 ab	27.2 ab	28.4 a	29.6 a	33.6 ab
Monostearin					
0.2%	28.0 ab	25.2 a	26.0 a	28.4 a	34.0 ab
0.4%	25.6 a	25.2 a	26.4 a	30.0 a	29.6 a

[a] Scores expressed as mean force (kg) and represent four determinations for each of four replications. Tortillas were stored at 4°C through day 3 or at −20°C for 30 days.
[b] Means within each column with different letters indicate $P < 0.05$ between products.

TABLE II
Sensory Evaluation Scores for Fresh and Stored Tortillas[a]

Monoglyceride Added	Day[b] 0	1	2	3	30
Firmness scores[c]					
Control	3.3 c	3.2 b	3.3 a	4.3 a	3.5 c
Monomyristin					
0.02%	4.6 ab	3.9 ab	4.2 a	4.8 a	5.3 a
0.04%	5.3 a	4.6 ab	4.1 a	4.8 a	5.2 a
Monopalmitin					
0.02%	4.4 b	4.7 a	3.9 a	4.0 a	4.9 ab
0.04%	5.3 a	4.1 ab	3.9 a	4.4 a	4.7 ab
Monostearin					
0.02%	4.7 ab	4.9 a	4.4 a	4.6 a	4.0 bc
0.04%	5.4 a	5.2 a	3.9 a	4.1 a	5.1 ab
Rollability scores[d]					
Control	6.0 b	4.4 a	4.0 a	4.5 b	4.0 a
Monomyristin					
0.02%	6.6 a	5.9 a	4.9 a	5.9 a	5.5 a
0.04%	6.5 a	5.3 a	4.6 a	5.6 ab	5.5 a
Monopalmitin					
0.02%	6.4 a	5.2 a	4.1 a	5.2 ab	5.4 a
0.04%	6.5 a	4.7 a	4.3 a	4.8 ab	5.2 a
Monostearin					
0.02%	6.2 ab	4.9 a	4.6 a	5.5 ab	5.7 a
0.04%	6.3 ab	4.1 a	4.3 a	5.2 ab	5.1 a
Dryness scores[e]					
Control	3.3 c	3.0 a	3.0 b	3.6 c	4.5 b
Monomyristin					
0.02%	4.7 ab	3.6 a	4.1 ab	4.7 ab	5.9 a
0.04%	5.3 a	4.2 a	4.7 a	5.3 a	5.6 ab
Monopalmitin					
0.02%	4.5 b	4.4 a	3.6 ab	4.3 bc	5.2 ab
0.04%	5.3 a	3.7 a	3.8 ab	4.2 bc	4.8 ab
Monostearin					
0.02%	5.0 ab	4.1 a	3.9 ab	4.9 ab	5.5 ab
0.04%	5.3 a	4.3 a	3.8 ab	4.5 b	5.2 ab

[a] Within each score category, means in a column followed by different letters indicate $P < 0.05$ between products. Scores represent four replicate evaluations by 10–12 panelists.
[b] Tortillas were stored at 4°C through day 3 or at −20°C for 30 days.
[c] 1 = Very firm, 4 = moderately soft, 7 = very soft.
[d] 1 = Not easily rolled (breaks apart), 4 = rollable (some cracks), 7 = very rollable (no cracks).
[e] 1 = Very dry, 4 = moderately moist, 7 = very moist.

TABLE III
Instron Values for Masa Harina Doughs[a]

Monoglyceride Added	Peak 1[b] Peak Area	Peak 2[c] Peak Height
Control	26.7 b	10.4 a
Monomyristin		
0.2%	28.8 ab	6.0 ab
0.4%	31.3 ab	5.6 b
Monopalmitin		
0.2%	31.6 ab	6.0 ab
0.4%	32.7 a	6.4 ab
Monostearin		
0.2%	31.0 ab	7.6 ab
0.4%	32.3 a	6.4 ab

[a] Means within each column with different letters indicate $P < 0.05$ between products. Scores represent three determinations for each of three replications.
[b] Scores expressed as mean peak area (cm^2).
[c] Scores expressed as mean force (kg).

TABLE IV
Visco/Amylograph Values for Masa Harina Flour-Water Slurries[a]

Monoglyceride Added	Peak Viscosity (BU)[b]	Pasting Temperature (°C)	Viscosity at 50°C (BU)[b]
Control	437 d	72.5 d	807 c
Monomyristin			
0.2%	498 c	76.3 b	990 ab
0.4%	550 a	79.0 a	1,000 a
Monopalmitin			
0.2%	512 bc	74.8 c	963 b
0.4%	548 a	76.2 b	995 ab
Monostearin			
0.2%	517 b	73.5 d	977 ab
0.4%	535 a	72.4 d	995 ab

[a] Means within each column with different letters indicate $P < 0.05$ between products. Scores represent three determinations for each of three replications.
[b] Brabender units.

causing an initial firming of bread, but that continued firming (and staling) during bread storage is likely due to crystallization of the amylopectin (Kim and D'Appolonia 1977; Pisesookbonterng and D'Appolonia 1983a,b). The role of MGs in reducing staling, then, is likely related to MG interactions with both amylose and amylopectin. Krog (*personal communication*, 1985) suggested that MS can complex better with amylose than can MM and MP. Riisom et al (1984) reported that MM and MP have identical abilities to complex with amylose. Batres and White (1986) found that MP was best at complexing with potato amylopectin, followed by MM and MS.

Perhaps the preservation effects of the MGs in the tortillas are related to their different abilities to complex with amylose and amylopectin. Those MGs most able to complex with amylose (MS) would then exhibit the most effect at the beginning of storage when amylose recrystallizes. After storage, those MGs most able to complex with amylopectin (MP and MM) would have the greatest effect.

The cereal system in this study was tortillas rather than breads, and corn rather than wheat starch, so caution is necessary in drawing major conclusions.

Instron Measure of the Masa Harina Doughs

Dough machinability. The Instron test to measure the machinability of a dough was conducted on the control and on six different doughs that contained MGs (0.2 and 0.4% MM, MP, and MS). The results are presented in Table III. According to De Padua and Padua Maroun-Ciepe (1984), peak 1 represents the firmness of the dough, while peak 2 reflects the adhesiveness of the dough (Fig. 1).

The height and area of peak 1 were measured, but because the area was more sensitive to the differences, it is reported. Generally, the addition of 0.4% MG resulted in firmer dough (greater peak area) than did the addition of 0.2% MG. The MS and MP were slightly more effective than MM at both levels, although the differences were not significant. The control dough tended to be softer than the other treatments. These results are similar to those of a number of researchers (Knightly 1973, Hoseney et al 1970, DeStefanis et al 1977, Garti et al 1980, Lorenz 1983), who reported that the addition of surfactants or MGs gave firmer, more machinable doughs. These doughs had a higher tolerance to mixing and were less susceptible to breakdown.

Peak 2 was very small, and an accurate measure of area was difficult. Therefore, peak height (mean force in kilograms) was used. Although not always significant, the control was the most adhesive (highest value). Generally, all MGs decreased dough adhesiveness, which should result in easier handling of doughs. Studies by Gorton (1985) found that the addition of distilled MGs to wheat pasta reduced the stickiness after cooking and maximized the cooked weight.

Visco/Amylograph Tests

The results of the Visco/Amylograph test are presented in Table IV. Slurries containing 10% masa harina flour with MGs (0.2 and 0.4% [flour weight] of MM, MP, or MS) and without MGs (control) were examined. Three slurries of each type were measured each of three days. Data were analyzed by ANOVA. All slurries containing MGs had significantly higher peak viscosities ($P < 0.05$) than the control. Slurries containing 0.4% MG had significantly higher peak viscosities ($P < 0.05$) than slurries containing 0.2% MG. These results agree with those of other researchers (Yasunaga et al 1968; Krog 1971, 1973; Riisom et al 1984), who reported that the addition of MGs to flour or starch slurries increases peak viscosity.

Some significant differences ($P < 0.05$) in pasting temperature were noted among the treatments. The slurries containing MM had the greatest pasting temperature, followed by slurries with MP and then MS.

The addition of all MGs to the systems significantly ($P < 0.05$) increased the viscosity at 50°C compared with the control. There were some significant differences ($P < 0.05$) among the treatments containing MG, with 0.4% MM having the greatest effect followed by MS and then MP.

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LITERATURE CITED

ADAMS, C. 1975. Nutritive value of American foods in common units. U.S. Dep. Agric. Agric. Handb. 456. U.S. Government Printing Office: Washington, DC

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC. Method 22-10, approved May 1960; Method 44-19, approved April 1961; Methods 46-12 and 76-11, approved October 1976. The Association: St. Paul, MN.

BATRES, L. V., and WHITE, P. J. 1986. Interaction of amylopectin with monoglycerides in model systems. J. Am. Oil Chem. Soc. 63:1537.

BEDOLLA, S. 1983. Development and characterization of an instant tortilla flour from sorghum and maize by infrared cooking (micronizing) and extrusion cooking. Ph.D. dissertation. Texas A&M University, College Station, TX.

BEDOLLA, S., and ROONEY, L. W. 1984. Characteristics of U.S. and Mexican instant maize flours for tortilla and snack preparation. Cereal Foods World 29:732.

BEDOLLA, S., DE PALACIOS, M. G., ROONEY, L. W., DIEHL, K. C., and KAHN, M. N. 1983. Cooking characteristics of sorghum and corn for tortilla preparation by several cooking methods. Cereal Chem. 60:263.

CHUNG, O. K. 1986. Lipid-protein interactions in wheat flour, dough, gluten, and protein fractions. Cereal Foods World 31:242.

DE PADUA, M. R., and PADUA MAROUN-CIEPE, H. 1984. Rheological behavior of Venezuelan *arepa* dough from precooked corn flour. Cereal Chem. 61:37.

DE STEFANIS, V. A., PONTE, J. G., CHUNG, H., and RUZZA, N. A.

1977. Binding of crumb softeners and dough strengtheners during breadmaking. Cereal Chem. 54:13.
ELAISSON, A. C., and KROG, N. 1985. Physical properties of amylose-monoglyceride complexes. J. Cereal Sci. 3:239.
GARTI, N., LINDNER, C., and PINTHUS, E.J. 1980. Evaluation of food emulsifiers in the bread baking industry. Baker's Dig. 54:24.
GORTON, L. 1984. Tortilla improvements. Baker's Dig. 58:26.
GORTON, L. 1985. Monoglycerides cut stickiness and help pasta withstand freeze/thaw cycling. Baker's Dig. 59:44.
HOSENEY, R. C., FINNEY, K. F., and POMERANZ, Y. 1970. Functional (breadmaking) and biochemical properties of wheat flour components. VI. Gliadin-lipid-glutenin interaction in wheat gluten. Cereal Chem. 47:135.
KIM, S. K., and D'APPOLONIA, B. L. 1977. The role of wheat flour constituents in bread staling. Cereal Chem. 54:216.
KNIGHTLY, W. H. 1973. The evolution of softeners and conditioners used in baked foods. Bakers Dig. 47:64.
KROG, N. 1971. Amylose complexing effect on food grade emulsifiers. Staerke 23:206.
KROG, N. 1973. Influence of food emulsifiers on pasting temperature and viscosity of various starches. Staerke 25:22.
KROG, N. 1977. Functions of emulsifiers in food systems. J. Am. Oil Chem. Soc. 54:124.
KROG, N., and JENSEN, B. N. 1970. Interaction of monoglycerides in different physical states with amylose and their anti-firming effects in bread. J. Food Technol. 24:77.
LAGENDIJK, J., and PENINGS, H. J. 1970. Relation between complex formation of starch with monoglycerides and the firmness of bread. Cereal Sci. Today 15:354.
LORENZ, K. 1983. Diacetyl tartaric acid esters of monoglycerides (DATEM) as emulsifiers in breads and buns. Bakers Dig. 57:6.
LUKE, T., and ANDRES, C. 1981. Tortilla shelflife increased by over 50%. Food Process. 42:32.
MIKUS, F. F., HIXON, R. M., and RUNDLE, R. E. 1946. The complexes of fatty acids with amylose. J. Am. Chem. Soc. 68:1115.
PISESOOKBONTERNG, W., and D'APPOLONIA, B. L. 1983a. Bread staling studies. I. Effect of surfactants on moisture migration from crumb to crust and firmness values of bread crumb. Cereal Chem. 60:298.
PISESOOKBONTERNG, W., and D'APPOLONIA, B. L. 1983b. Bread staling studies. II. The role of refreshening. Cereal Chem. 60:301.
RIISOM, T., KROG, N., and ERIKSEN, J. 1984. Amylose complexing capacities of *cis*- and *trans*-unsaturated monoglycerides in relation to their functionality in bread. J. Cereal Sci. 2:105.
RUSSELL, P. L. 1983. A kinetic study of bread staling by differential scanning calorimetry and compressibility measurements. The effect of added monoglyceride. J. Cereal Sci. 1:297.
WILLIAMS, P. C., KUZINA, F. D., and HLYNKA, I. 1970. A rapid colorimetric procedure for estimating the amylose content of starches and flours. Cereal Chem. 47:411.
YASUNAGA, T., BUSHUK, W., and IRVINE, G. N. 1968. Gelatinization of starch during bread-baking. Cereal Chem. 45:269.

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