Effects of Leavening Acids and Dough Temperature in Wheat Flour Tortillas

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ABSTRACT

Functionality of four leavening acids (sodium aluminum phosphate [SALP], sodium aluminum sulfate [SAS], monocalcium phosphate [MCP] and sodium acid pyrophosphate [SAPP-28]) was evaluated during processing of wheat flour tortillas. Formulas were optimized to yield opaque, large-diameter tortillas with pH 5.9–6.1. Each leavening acid and sodium bicarbonate was first evaluated at 38°C and then evaluated in combination with fumaric acid at 34 and 38°C. Ionic and pH interactions of leavening salts adversely affected dough properties and resting time. Opacity and pH of tortillas prepared with MCP was lower than for other treatments. Higher dough temperature required more leavening acid and base to compensate for some of the loss of CO_2 incurred during dough mixing and resting at 38°C. The addition of fumaric acid decreased the amount of leavening acid, the dough-resting time and tortilla pH, and improved storage stability. Combinations of MCP, SALP (or SAS), and fumaric acid produced dough and tortillas with good qualities. Tortillas prepared using SALP (or SAS) and fumaric acid tended to be of better quality.

Flour tortilla consumption in the United States has increased ≈20% per year over the last two decades. Large-scale, automated equipment was used to prouce ≈$2 billion dollars worth of flour tortillas in the United States in 1998. Consumption of tortillas in the United States, however, does not occur on the day of production as it commonly does in Mexico and Central America, but occurs 1–180 days later. Hence, ingredients in addition to flour, water, shortening, and salt are needed to produce tortillas with extended storage-stability (freshness) and shelf life (microbial). In the United States, the formula also includes chemical leavening, acidulants, preservatives, reducing agents, and emulsifiers (Serna-Saldivar et al 1988, Waniska 1999). Consumers frequently request tortillas with improved qualities like opacity, flexibility, thinness or thickness, etc. Hence, ingredients that yield tortillas with improved properties are currently being investigated.

Tortilla is flat, circular, light-colored bread (1–5 mm thick; 100–700 mm diam). Good quality tortillas are symmetrical, uniform, opaque, white, with toast spots and puffed (small or large areas with distinct layering) (Bello et al 1991, Waniska 1999). Leavening reactions help form a less dense, spongy product with a whiter and more opaque appearance (Serna-Saldivar et al 1988). Translucency (lack of opacity) is a defect in tortillas, probably related to the absence of small air bubbles in the baked tortilla. When light refracts from small air bubbles, the tortilla looks opaque. Formation of air bubbles in the dough and retention of air bubbles in the tortilla become critical issues in the production of uniformly opaque tortillas.

Leavening of flour tortillas results from air incorporated during mixing, carbon dioxide (CO_2) formed by chemical leavening reaction, expansion of air bubbles due to heat, and volatilization of water (Waniska 1999). Chemical leavening is a neutralization process where a bicarbonate is neutralized by an acid yielding carbon dioxide (Heidolph 1996). The volatilization of water can causes rapid increases in volume (Moore and Hoseney 1985) and may be responsible for puffing of tortillas. Controlled formation of small air bubbles probably result from the first two mechanisms.

Leavening acids vary in the rate and conditions of solubility and in the amount needed to neutralize bicarbonate (Holmes and Hoseney 1987, Heidolph 1996). Acids that hydrate and dissolve rapidly are fast-acting acids such as calcium phosphates (monocalcium phosphate [MCP]) and organic acids (citric, fumaric, lactic, and tartaric) (Heidolph 1996). About 70% of MCP reacts within the first 2 min of mixing at 27°C (Reiman 1983). Acids that become soluble during the baking process are slow-acting acids such as sodium aluminum phosphate (SALP), sodium acid pyrophosphate (SAPP) and sodium aluminum sulfate (SAS) (La Baw 1982). Fast-acting acids, like MCP, form thicker batter or dough compared with slower acting acids (Van Wazer 1961). Fast-acting acids are seldom used as a leavener by themselves (La Baw 1982), instead, fast-acting acids function as nucleating agents when combined with a slower reacting acid and sodium bicarbonate as in commercial, double-acting baking powder (Heidolph 1996).

Leavening acids are commonly evaluated at 27°C in a biscuit dough. However, tortilla dough is normally processed at 30–36°C and it contains less moisture (Serna-Saldivar et al 1988, Bello et al 1991, Friend et al 1993, Waniska 1999). Heildoph (1996) noted that higher dough temperatures and moisture levels accelerate solubilization of acids and generation of CO_2 by the leavening system. Tortilla dough system is not the same as that of bread because it involves a gluten dough structure with chemical leavening. Once the dough is formed, it is rested for sometime (similar to proofing) to allow the gluten to relax before pressing. When doughs are rested, less pressure, temperature and time are needed during pressing to produce thin and large diameter tortillas.

TABLE I
Formulation Used to Prepare Flour Tortillas

Ingredients[a,b]	Amount[c]
Wheat flour	1,000 g
Salt	1.5%
SSL	0.2%
SMG	0.2%
Sodium propionate	0.5%
Potassium sorbate	0.4%
Shortening	6.0%
Variable amounts of:	
Sodium bicarbonate	
Fumaric acid	
SALP	
SAS	
MCP	
SAPP-28	
Distilled water	

[a] Sources of ingredients in the order listed: ADM Milling Co., United Salt Corp., Houston, TX, American Ingredients Co., Kansas City, MO, Eastman Chemical Co., Kingsport, TN, American Ingredients Co., Kansas City, MO, Haarmann and Reimer Co., Elkhart, IN, Anderson Clayton Foods, Inc., Dallas, TX, Commercial baking soda, Church and Dwight Co., Princeton, NJ, Bartek Ingredients, Inc., Stoney Creek, Ontario, Monsanto, St. Louis, MO, General Chemical Co., Parsippany, NJ, Levn-lite, Monsanto, St. Louis, MO, Monsanto, St. Louis, MO.

[b] SSL = sodium stearoyl-2-lactate, SMG = sodium monoglycerides, SALP =s odium aluminum phosphate, SAS = sodium aluminum sulfate, MCP = monocalcium phosphate anhydrous, SAPP-28 = odium acid phosphate-28.

[c] Amounts on minor ingredients are expressed on flour basis.

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We suspect that more acid solubilizes and reacts with the bicarbonate in tortilla dough at higher dough temperatures. This would then diminish CO_2 production during the tortilla baking process but would not affect opacity of tortillas if all generated CO_2 were retained in the dough and tortilla. If CO_2 is lost during the processing, however, the amount of leavening ingredients in the formula could generate more CO_2 during processing to yield more opaque tortillas.

Higher dough mixing temperature decreases mixing time of flour-water dough (3.9 min/10°C increase) (Hlynka 1962) and decreases the storage modulus (G') of dough as temperature increases from 24 to 50°C (Dreese et al 1988). Higher dough temperature, therefore, should increase mixer throughput and decrease dough-resting time. These may be the reasons higher dough temperatures are commonly used in the tortilla industry (Waniska 1999). However, higher dough temperature causes earlier solubility and reaction of leavening ingredients and increased levels of baking powder and leavening reaction by-products, including multivalent ions. The multivalent ions and pH levels resulting from the leavening reactions can influence dough properties (Holmes and Hoseney 1987). Gluten is weakened by sulfate ions, whereas cream of tartar and phosphates strengthen gluten (Van Wazer 1961, Kichline and Conn 1970). A SAS-based leavening system is suitable in flour tortilla production when the dough was mixed at an unspecified temperature (La Baw 1982). The SAS-based leavening system imparted blistering during cooking and yielded tortillas with a tender texture.

A pH ≤ 6.1 in the tortilla is required to realize significant activity while pH < 5.5 yields substantial activity from the same amount of propionate- or sorbate-based preservatives (Friend et al 1995). As dough pH decreases to pH < 6.3, gluten becomes increasingly more solid-like and difficult to extend or machine (Waniska 1999). Fumaric acid, a fast-acting acid, effectively lowers tortilla pH without causing as many dough machinability problems as other acidulants (Friend et al 1995). Dough machinability involves dough handling, rounding, and disk-forming properties that directly affect the shape, size, thickness, and appearance of tortillas (Bello et al 1991). Stiff and poor-machinable doughs require longer to mix, cause extended resting times, and produce tortillas that are off-round, rough, and with little puffing (Suhendro et al 1993, Friend et al 1995).

The objectives of this research were to evaluate the effects of leavening acids and dough temperature during production and on properties of wheat flour tortillas.

MATERIALS AND METHODS

Formula

Enriched, unbleached wheat flour with 10.5% protein was used to prepare hot-pressed wheat flour tortillas. The flour had 12.0% moisture content, pH 5.9, and mixograph mixing time of 4.5 min (AACC 2000). The base tortilla formula is listed in Table I.

Processing

Tortillas were processed using the procedure described by Bello et al (1991) with modifications (Fig. 1): shortening was mixed at low speed for 6 min, dough temperature was controlled using 38°C water and with an electrical heating strip in an insulated jacket around the mixing bowl. A voltage regulator (type 116B, W.H. Curtin and Co.) controlled the temperature. The hot-press (model G6201, Bakery and Supply Co., San Antonio, TX) uses a rotating cam to deliver pressure to the vertically oscillating top platen. The compression cycle is much shorter and provides more force than hydraulic-driven hot-presses. The platen temperatures were 218°C (top) and 204°C (bottom).

Strategy and Experimental Design

We used extreme processing conditions (38°C dough temperature, variable dough ball resting time [19–133 min], and 0.8-sec hot-press dwell time) and optimum tortilla characteristics (uniform, >16.5 cm diam, maximum [100%] opacity, pH 5.9–6.1) to differentiate functionality of leavening acids. We optimized each formula to attain machineable dough and tortillas with near-target properties. The amounts of base and leavening acids were calculated using the appropriate neutralization values (Dubois 1981). Subsequently, more acid was used to lower the pH level. Some treatments, however, did not produce optimum dough or tortilla properties.

TABLE II
Effects of Leavening Acids on Dough and Tortilla Properties

Leavening Acid (g/kg)	Sodium Bicarbonate (g/kg)	Water Absorption (g)	Dough Properties: Smoothness[a]	Softness[b]	Toughness[c]	Resting Time (min)	Tortilla Properties: Height (cm)	Diameter (cm)	Specific Vol.[d] (cm^3/g)	pH	Opacity[e]
Sodium aluminum phosphate (SALP)											
8.0	4.5	485	4.7	4.7	4.7	25.0	0.29	17.2	1.79	6.3	4.6
10.0	5.6	485	4.5	4.5	4.1	33.0	0.31	17.2	1.79	6.4	4.7
12.0	6.8	485	4.4	4.5	4.3	29.7	0.32	17.5	2.00	6.4	4.8
14.0	8.0	485	4.0	4.5	4.3	37.0	0.33	17.0	1.96	6.4	5.0
Sodium aluminum sulfate (SAS)											
6.0	5.3	500	4.7	4.7	4.6	27.0	0.30	17.1	1.76	6.0	4.7
8.0	7.0	505	4.8	4.9	4.9	30.0	0.32	17.1	1.81	6.1	4.8
9.8	9.0	505	4.3	4.8	4.8	38.0	0.30	16.4	1.61	6.2	4.8
Monocalcium phosphate (MCP)											
24.0	8.0	495	4.5	4.8	4.8	25.0	0.26	16.6	1.40	6.0	3.7
30.0	10.0	495	4.4	4.5	4.4	45.0	0.31	16.1	1.54	5.9	3.8
36.0	12.0	495	4.5	4.5	4.5	68.0	0.27	16.3	1.40	5.8	3.5
42.0	14.0	495	4.5	4.2	4.0	133.0	0.28	16.3	1.37	5.8	3.6
Sodium acid pyrophosphate-28 (SAPP-28)											
22.0	5.0	487	5.0	5.0	5.0	40.0	0.29	16.6	1.60	6.3	4.4
26.0	6.0	487	5.0	5.0	5.0	41.0	0.28	16.2	1.49	6.3	4.4
30.0	7.0	487	5.0	5.0	5.0	50.0	0.27	17.0	1.58	6.3	4.4
35.0	8.0	487	4.3	5.0	5.0	39.0	0.31	15.8	1.65	6.3	4.8
LSD[f]			0.8	0.4*	0.5*	15.5*	0.05*	0.9*	0.28*	0.1*	0.4*

[a] Smoothness: continuous scale 1–5 (1 = rough and 5 = smooth).
[b] Softness: continuous scale 1–5 (1 = less viscous, 5 = soft, more viscous).
[c] Toughness: continuous scale 1–5 (1 = excessively elastic, 5 = less tough, less elastic).
[d] Specific volume = volume/weight.
[e] Opacity: continuous scale 1–5 (1 = translucent, 5 = opaque).
[f] Least significant difference; * denotes significantly different at $\alpha = 0.05$.

Individual leavening acids (SALP, SAS, SAPP-28, MCP) at several levels were evaluated initially. Because some tortillas did not have a pH ≤ 6.1, fumaric acid (0.29%) was added to lower pH levels. Fumaric acid was used to lower dough pH level because doughs with fumaric acid pressed into larger diameter tortillas than with citric acid (Friend et al 1995). The effect of dough temperature was then determined using sodium bicarbonate, fumaric acid, and SALP, SAS, MCP, or SAPP-28. Then, two three-leavening acid systems, composed of sodium bicarbonate, fumaric acid, and SALP or SAS, were evaluated.

Dough Properties

Dough was subjectively evaluated for smoothness, softness, and toughness. Smoothness refers to the appearance and texture of the dough surface; softness refers to the viscosity or firmness of the dough is when compressed; and toughness refers to elasticity of the dough when pulled apart. Each property was rated using a continuous scale of 1–5: 5 = very smooth, very soft or least tough; 4 = smooth, soft, or slightly tough; 3 = slightly smooth, slightly hard, or tough; 2 = rough, hard, or very tough; and 1 = very rough, very hard, or extremely tough.

Tortilla Properties

The height, diameter, weight, pH level, and opacity of baked tortillas were determined (Bello et al 1991). Specific volume was calculated. Opacity was measured subjectively using a continuous scale of 1–5: 1 = 100% translucent; 2 = 75% translucent, 25% opaque; 3 = 50% translucent, 50% opaque; 4 = 25% translucent, 75% opaque; and 5 = 100% opaque.

Storage stability of tortillas was determined using the rollability test (Friend et al 1995). Rollability was evaluated by wrapping a tortilla around a dowel (1.0 cm diam) and rating the cracking and breakage of the sample. A continuous scale of 1–5 was used: 5 = no cracking; 4 = signs of cracking, but no breaking; 3 = cracking and breaking beginning on the surface; 2 = cracking and breaking imminent on both sides; and 1 = unrollable, breaks easily.

Statistical Analysis

The effects of processing conditions on tortilla quality were evaluated with one way analysis of variance in a completely randomized experimental design. Protected Fisher's LSD was used for multiple mean comparisons. SAS statistical software package was used to conduct statistical analysis (SAS Institute, Cary, NC).

RESULTS

Effect of One Leavening Acid

The objective of producing uniform dough and tortillas despite differences in formulation was essentially met as shown in Table II. Only small variations in dough and tortilla properties were observed. Opacity of tortillas, however, did not increase as much as expected when leavening compounds were increased. We did not include treatments with lower levels of leavening compounds that exhibited considerable translucency because our target was an opaque product.

Dough and tortilla properties were more affected by the type of leavening acid than with the amount used in the formula (Table II). Dough containing SAPP-28 tended to have higher (better) ratings

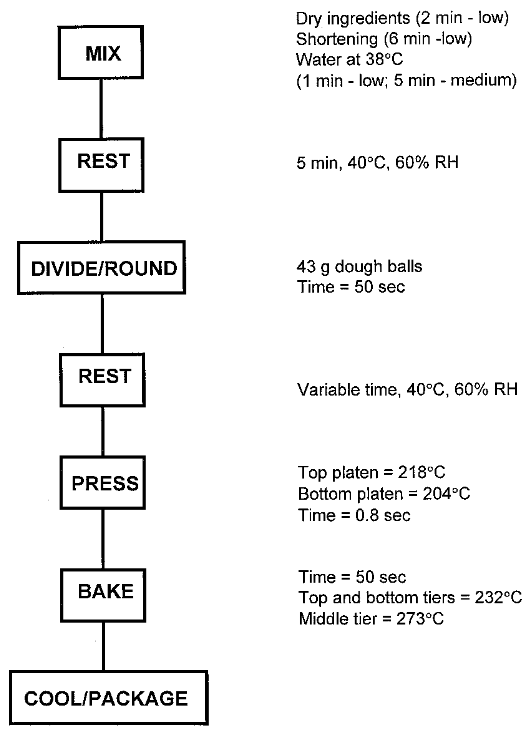

Fig. 1. Process flow chart for hot-press flour tortillas.

TABLE III
Effects of Dough Temperature and Two Leavening Acids on Dough and Tortilla Properties

Leavening Acid (g/kg)	Fumaric Acid (g/kg)	Sodium Bicarbonate (g/kg)	Water Absorption (g)	Dough Temperature (°C)	Dough Properties: Smoothness[a]	Softness[b]	Toughness[c]	Resting Time (min)	Tortilla Properties: Height (cm)	Diameter (cm)	Specific Vol.[d] (cm^3/g)	pH	Opacity[e]
Sodium aluminum phosphate (SALP)													
5.2	2.9	6.0	485	34	4.1	4.6	4.4	23.3	0.30	16.9	1.62	5.8	4.8
7.7	2.9	8.0	485	38	4.4	4.7	4.7	28.8	0.33	17.1	1.88	6.1	4.8
Sodium aluminum sulfate (SAS)													
5.3	2.9	8.0	482	34	3.9	4.1	4.1	37.8	0.31	17.1	1.69	5.9	4.8
4.9	2.9	8.0	489	38	4.5	4.6	4.5	22.9	0.32	16.6	1.64	6.0	4.7
Monocalcium phosphate (MCP)													
7.8	2.9	7.0	482	34	3.9	4.6	4.2	21.7	0.26	16.6	1.60	6.0	4.3
9.8	2.9	8.0	482	38	4.4	4.4	4.4	28.3	0.29	16.4	1.55	6.2	4.1
Sodium acid pyrophosphate-28 (SAPP-28)													
8.6	2.9	7.0	487	34	4.2	4.6	4.5	26.0	0.31	15.8	1.54	6.2	4.4
13.5	2.9	8.0	487	38	4.6	4.9	4.7	24.7	0.32	16.0	1.60	6.2	4.5
LSD[f]					1.0	0.6*	0.8*	9.7*	0.05	1.3	0.37	0.2*	0.4*

[a] Smoothness: continuous scale 1–5 (1 = rough and 5 = smooth).
[b] Softness: continuous scale 1–5 (1 = less viscous, 5 = soft, more viscous).
[c] Toughness: continuous scale 1–5 (1 = excessively elastic, 5 = less tough, less elastic).
[d] Specific volume = volume/weight.
[e] Opacity: continuous scale 1–5 (1 = translucent, 5 = opaque).
[f] Least significant difference; * denotes significantly different at $\alpha = 0.05$.

for smoothness, softness, and toughness compared with dough prepared using other leavening acids that had similar ratings. This may be attributed to the ionic interactions of SAPP reaction products with gluten (Van Wazer 1961). Tougher dough tended to be observed in treatments containing more SALP or MCP.

Substantially longer dough resting times were needed when more MCP was used. Dough resting time also tended to increase in treatments containing more SALP or SAS. We learned that dough resting time is not an easy variable to control, as exhibited by the long times and high variability.

The type of leavening acid significantly affected pH level, opacity, and specific volume of tortillas (Table II). However, increasing the amount of leavening acid did not significantly affect these properties. Tortillas prepared with MCP had the lowest pH (5.9), opacity (3.6), and specific volume (1.43 cm^3/g) values. The pH level of tortillas prepared using SAS (pH 6.1) were also within the pH target; but tortillas prepared with SALP (pH 6.4) and SAPP-28 (pH 6.3) were above the pH target. Specific volume of tortillas prepared with SAPP-28 tended to be lower than those prepared using SALP or SAS. Increasing the amount of leavening acid tended to increase tortilla opacity (SALP, SAPP-28) and specific volume (SALP).

We increased the amount of leavening acid in this study to decrease the pH level in the tortilla because tortilla pH should be <6.1 to activate the preservatives (Friend et al 1995). The excess leavening acid did not decrease pH level very much, but it contributed to the buffer capacity or it remained undissolved during tortilla processing. The taste of tortillas containing unreacted SAPP-28 was a characteristic bitter or "pyro" aftertaste (Heidolph 1996 and *personal observations*). To overcome this problem, a faster acting SAPP should be evaluated. The taste of tortillas containing excess SALP or SAS was not as objectionable (*personal observations*). No individual leavening acid, however, yielded tortillas with optimum opacity, specific volume, and pH.

There appears to be no advantage to increasing the amount of a single-leavening acid baking powder because it did not translate into improved dough or tortilla properties. The perception in the tortilla industry is that increasing the amount of baking powder will improve both dough and tortilla properties. Instead, insignificant improvements were observed with SALP, SAS, and SAPP, while adverse effects were observed using MCP. The increased solubility of MCP at 38°C probably caused the dough pH level to be lower than other treatments, which contributed to the earlier generation of gas bubbles, longer resting times, and lower tortilla pH level. Lowering tortilla dough pH level from 5.8 to 5.5 increased protein aggregation, which adversely affected dough machinability, moistness, elasticity, and pliability (Friend et al 1995). Among the slower acting acids, SALP and SAS yielded slightly better tortillas on the basis of opacity and specific volume than did SAPP-28.

Effects of Dough Temperature and Two Leavening Acids

Fumaric acid (0.29%) was added to lower pH (target pH 5.9-6.1) because some tortillas (above) had a pH > 6.1 and most commercial baking powders contain two or more leavening acids, sodium bicarbonate, and a filler (Reiman 1977). Fumaric acid is a fast-acting acid (Heidolph 1996) that should act as a nucleating agent and lower tortilla pH level. Formulas were optimized for each leavening acid and for each dough temperature (Table III). Generally, more leavening ingredients were required at 38°C than at 34°C dough temperature to yield tortillas with comparable opacity, diameter, and pH level.

Similar dough properties were observed despite varying dough temperature, addition of fumaric acid, or the type of leavening acid (Tables II and III). Increasing dough temperature decreased dough resting time in the SAS treatment but increased dough resting times in the SALP and MCP treatments. Dough resting time also decreased by the addition of fumaric acid in SALP, SAS, and SAPP-28 treatments. This was attributed to the reducing effect of fumaric acid, through a free radical mechanism that stabilizes sulfhydryl groups of protein resulting in a gluten structure with fewer disulfide cross-links (Sidhu et al 1980).

Dough temperature and the type of leavening acid generally did not affect tortilla pH, opacity, or specific volume (Tables II and III). Tortilla pH level was in the target pH range for SALP and SAS treatments (Table III). More fumaric acid could have been added

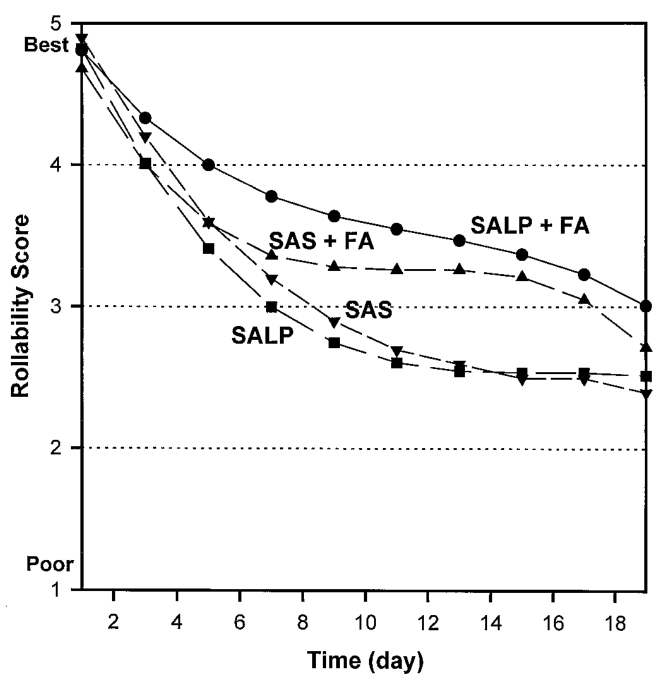

Fig. 2. Effects of sodium aluminum phosphate (SALP) and sodium aluminum sulfate (SAS) with or without fumaric acid (FA) on rollability of tortillas. Dough mixed at 38°C; SALP = 14 g/kg; SALP + FA= 7.7 g/kg SALP + 2.9 g/kg FA; SAS = 8 g/kg; SAS + FA = 4.9 g/kg SAS + 2.9 g/kg FA; overall least significant difference = 0.43, $\alpha = 0.05$.

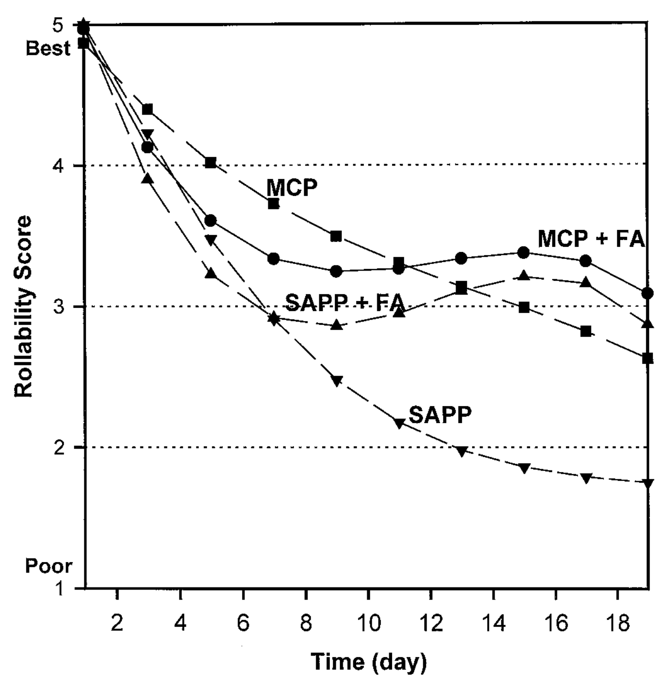

Fig. 3. Effects of monocalcium phosphate (MCP) and sodium pyrophosphate-28 (SAPP-28) with or without fumaric acid (FA) on rollability of tortillas. Dough mixed at 38°C; MCP = 24 g/kg; MCP + FA = 9.8 g/kg MCP + 2.9 g/kg FA; SAPP-28 = 35 g/kg; SAPP-28 + FA = 13.5 g/kg SAPP-28 + 2.9 g/kg FA; overall least significant difference = 0.49, $\alpha = 0.05$.

to MCP and SAPP-28 treatments to lower the pH into the target range. Tortilla opacity was not affected by dough temperature nor the addition of fumaric acid, except for MCP treatments where opacity increased (Table III). The MCP-leavened tortillas, however, were still the least opaque, while SALP and SAS tortillas had higher opacity ratings. Fumaric acid improved but was unable to correct the translucency or specific volume in the MCP-leavened tortillas. These observations indicate that fumaric acid is less soluble in the dough system than MCP at 34 and 38°C.

Storage stability of tortillas was affected by leavening acid and addition of fumaric acid (Figs. 2 and 3). Higher (better) rollability scores were observed beyond the 8th day of storage when fumaric acid was combined with SALP, SAS, and SAPP-28. Fumaric acid did not significantly improve tortillas prepared with MCP. A previous study had shown that fumaric acid improved the storage stability of flour tortillas when SALP was a component of the leavening system (Friend et al 1995). Rollability scores of tortillas containing added vital wheat gluten were improved (Suhendro et al 1993); this was attributed to improved gluten functionality. The lower pH level in the dough caused by fast-acting leavening acids such as fumaric acid and MCP may have changed gluten functionality (Hoseney and Brown 1983); this improved tortilla rollability in this study. Dough temperature did not significantly affect tortilla rollability (data not shown).

Increased amounts of leavening acid and sodium bicarbonate were required at 38 vs. 34°C to attain similar dough and tortillas, except for the SAS treatment where the amount deceased slightly (from 5.3 to 4.9 g/kg) (Table III). The higher temperature causes increased solubility of the leavening acid and base, even with the slow-acting leavening acids. Hence, more CO_2 should be produced by the leavening reaction during mixing and resting, and less CO_2 should be produced during baking of tortillas, yielding less opaque (more translucent) tortillas. Increasing the levels of acid and base, therefore, effectively compensated for the loss of CO_2 incurred during dough mixing and resting in these treatments.

Effect of Three Leavening Acids

Many manufacturers use double-acting baking powder along with added sodium bicarbonate and an acidulant (Waniska 1999). The resulting tortillas vary in opacity, thickness, and shelf life, depending, primarily, on the reactions in the leavening system, tortilla pH level, and preservatives. The effects of baking powder (type and amount) with added fumaric acid at 38°C were investigated in this study while attempting to maintain optimum tortilla properties. Baking powder based on MCP-SALP or MCP-SAS (Pyler 1982) was evaluated (Table IV).

Dough properties were only slightly affected by the leavening system. However, tortilla pH level and opacity were affected (Table IV). The MCP-SALP treatments tended to have larger values for specific volume than did the MCP-SAS treatments. Increasing the amount of leavening acid increased both pH level and opacity. More fumaric acid was added as the levels of MCP-SALP increased; but these adjustments were not sufficient to maintain the pH in the target pH range. Thus, when additional baking powder is added to increase the opacity of tortillas, more acidulant is also required.

Storage stability of tortillas prepared with MCP-SALP tended to be better throughout storage than tortillas prepared with MCP-SAS (Fig. 4). Rollability scores of these tortillas, however, were not

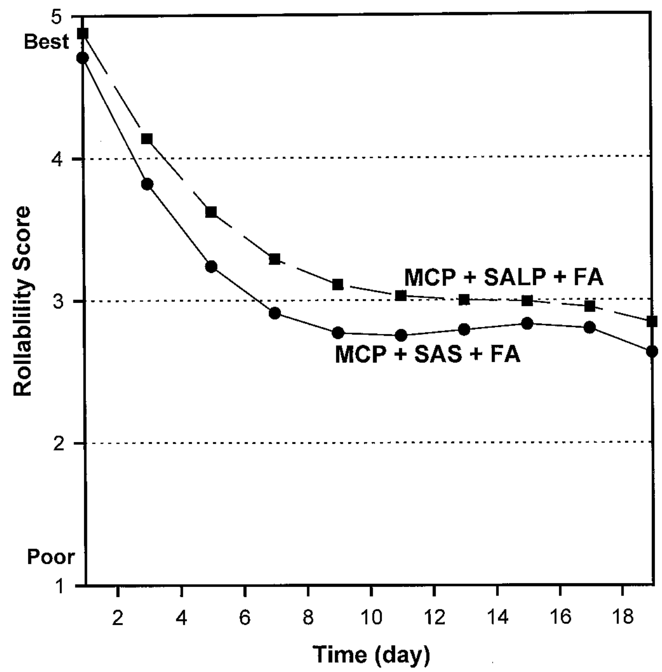

Fig. 4. Comparison of two mixtures of three leavening acids on rollability of tortillas. Dough mixed at 38°C; monocalcium phosphate (MCP) + sodium aluminum phosphate (SALP) + fumaric acid (FA) = 1.8 g/kg MCP + 9.2 g/kg SALP + 3.4 g/kg FA; monocalcium phosphate (MCP) + sodium aluminum sulfate (SAS) + fumaric acid (FA) = 3.7 g/kg MCP + 7.3 g/kg SAS + 2.8 g/kg FA; overall least significant difference = 0.46, α = 0.05.

TABLE IV
Effects of Two Combinations of Three Leavening Acids on Dough and Tortilla Properties

Leavening Acid (g/kg)	Fumaric Acid (g/kg)	Sodium Bicarbonate (g/kg)	Water Absoption (g)	Dough Properties: Smoothness[a]	Softness[b]	Toughness[c]	Resting Time (min)	Tortilla Properties: Height (cm)	Diameter (cm)	Specific Vol.[d] (cm^3/g)	pH	Opacity[e]
Monocalcium phosphate-Sodium aluminum phosphate (1:5)												
5.0	2.0	5.0	495	4.6	4.7	4.6	25.0	0.33	17.2	1.97	6.1	4.4
7.0	2.6	7.0	495	4.7	4.8	4.7	19.0	0.35	17.0	1.93	6.1	4.8
9.0	3.1	9.0	495	4.1	4.3	4.2	20.0	0.36	17.0	1.99	6.3	4.9
11.0	3.4	11.0	495	4.4	4.6	4.5	20.3	0.36	17.1	2.06	6.4	4.9
Monocalcium phosphate-Sodium aluminum sulfate (1:2)												
7.0	2.8	7.0	495	4.4	4.6	4.6	24.0	0.31	16.1	1.57	5.8	4.5
9.0	2.8	9.0	495	4.3	4.6	4.7	27.0	0.34	16.6	1.73	6.0	4.7
11.0	2.8	11.0	495	4.2	4.4	4.4	28.0	0.34	16.8	1.76	6.2	4.9
LSD[f]				0.8	0.5*	0.6	5.4*	0.08	1.4	0.44	0.2*	0.3*

[a] Smoothness: continuous scale 1–5 (1 = rough and 5 = smooth).
[b] Softness: continuous scale 1–5 (1 = less viscous, 5 = soft, more viscous).
[c] Toughness: continuous scale 1–5 (1 = excessively elastic, 5 = less tough, less elastic).
[d] Specific volume = volume/weight.
[e] Opacity: continuous scale 1–5 (1 = translucent, 5 = opaque).
[f] Least significant difference; * denotes significantly different at α = 0.05.

significantly better than those prepared with SALP (or SAS) and fumaric acid (Fig. 2).

In this study, 7 g/kg of MCP-SALP combined with 2.6 g/kg of fumaric acid and 7 g/kg of sodium bicarbonate yielded better quality tortillas. Likewise, 11 g/kg of MCP-SAS combined with 2.8 g/kg of fumaric acid, and 11 g/kg of sodium bicarbonate yielded better quality tortillas. These optimum levels, however, did not produce better tortillas than those containing only SALP (or SAS), fumaric acid, and sodium bicarbonate (Table III). Similarly, significant advantages were not realized by the addition of MCP into multicomponent leavening systems for biscuits (Conn and Jelinek 1983).

DISCUSSION

Extreme process conditions were used to differentiate functionality of leavening acids. The 0.8-sec compression cycle of the hot press is shorter, and the rotating cam delivers more pressure than does hydraulic-driven commercial equipment. Large air bubbles in the dough ball could be degassed during the formation of the thin disk during hot pressing. The process conditions used probably contributed to the less than optimal opacity of the tortillas evaluated.

The perception in the tortilla industry is that increasing the amount of baking powder will increase thickness and opacity of tortillas. Instead, we observed small or insignificant improvements using more SALP, SAS, and SAPP (alone or with fumaric acid), while adverse effects were observed using more MCP (alone). These results suggest that the tortilla manufacturer needs to be concerned with the type, amount, and proportion of leavening acids, and when leavening acids dissolve and react with sodium bicarbonate to leaven the dough and tortilla.

The faster acting acid, MCP, did not yield good opaque tortillas regardless of the amount used, with or without fumaric acid. The rapid solubility of MCP and subsequent reaction with sodium bicarbonate yielded CO_2 in the warm (38°C) dough. Some of the CO_2 was lost to the atmosphere during mixing and was not retained in the dough because the tortillas were not as opaque as other treatments. Fumaric acid, another fast-acting acid, functioned as an acidulant, dough relaxant, and a leavening acid slower than MCP.

Among the slow-acting acids, SALP and SAS yielded tortillas with higher (better) ratings and values than did SAPP-28. Tortillas prepared with SAPP-28 (two-acid formula) were close in quality to the SALP and SAS treatments. Addition of fumaric acid substantially improved tortillas containing SAPP-28 by eliminating the strong “pyro” aftertaste and reduced dough resting time. The specific volume of tortillas prepared with SALP (one-, two- and three-leavening acid formulas) were numerically higher but not statistically different from tortillas prepared with SAS or SAPP-28. Combination of fumaric acid with SALP or SAS resulted in significant improvements in storage stability of tortillas. Combination of three leavening acids did not result in significantly better dough nor tortillas as compared with the two leavening acid formulas.

Increasing the dough temperature from 34 to 38°C increased the amounts of leavening ingredients needed to prepare optimum tortillas with SALP, SAPP-28, and MCP. The leavening reaction increasingly occurred in the warm dough, which depleted the potential for bubble enlargement later during tortilla processing. This yields less opaque (more translucent) tortillas. Increasing the levels of acid and base, therefore, compensated for the loss of CO_2 incurred during dough mixing and resting. The slow-reacting SAS did not dissolve as much in the warm dough, as evidenced by the small decrease in amount required at 38°C. The leavening system in tortillas must include both functions of air bubble nucleation and enlargement of preexisting air bubbles at the appropriate times.

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