NOTE

Effect of Emulsifiers on Textural Properties of Whole Wheat Tortillas During Storage

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Flour tortillas are one of the most popular and successful products in the baking industry (Hillebrand 2005). Texture and organoleptic characteristics of tortillas are major criteria that consumers use to judge the overall quality. Good quality tortillas should stay flexible and rollable without cracking and breaking when folded, and be soft without sticking together (Wang and Flores 1999). One of the major problems in tortilla quality is the deterioration of texture with time due to staling (Waniska 1999).

Shelf life of tortillas can be improved through ingredients and formulation. Emulsifiers, a subset of surfactants, may impart antistaling characteristics aside from their emulsifying action (Stampfli and Nersten 1995; Seyhun et al 2003) and have been widely used by the baking industry.

Sodium stearoyl lactylate (SSL), an anionic surfactant, is primarily used as a dough strengthener and a crumb softener in the baking industry. It is believed that SSL interacts with gluten during mixing, resulting in improved dough strength, and then forms a complex with amylose and amylopectin during baking. This results in crumb softening by retarding the starch staling process (DeStefanis 1977; Bernardin 1978). The strong association between SSL and gluten at the dough stage has been suggested to delay denaturation and setting of gluten during baking (Stauffer 1999). After baking, most of the SSL interacts hydrophobically with starch, which is thought to reduce the rate and extent of staling (Chung 1986).

Glyceryl monostearate (GMS) is a derivative from α-monoglycerides and is known to improve texture. Similar to SSL, GMS has the ability to form complexes with amylose, hence, inhibiting the firming of baked goods due to staling (Krog and Nybu-Jensen 1970). The N-alkyl portion of GMS forms a complex with the helical regions of amylose, a phenomenon that is thought to be responsible for its effect in retarding starch crystallization, slowing the staling process. The interaction between GMS and amylose takes place at the surface of the granules, and the amylose-emulsion complex serves to stabilize the granule, retarding water penetration and swelling as the temperature is raised (Stauffer 1999).

Soybean lecithin, an amphoteric surfactant, is a natural emulsifier and a mixture of phosphatides. Lecithin, unlike SSL and GMS, does not form a complex with the starch; (Stampfli and Nersten 1995). Instead, it interacts with flour gluten in baked products to extend shelf life. Lecithin is classified as a GRAS substance with a long history of safe food applications (McCormick 1986).

According to dietary guidelines for Americans published by the USDA, 100 g of enriched, bleached, all-purpose white flour contains only 2.7 g of dietary fiber, whereas 100% whole wheat (WW) flour has 12.2 g of fiber/100 g of flour. Even though the importance of dietary fiber has been stressed by health organizations, including USDA, the average intake of dietary fiber of Americans is less than the recommended average by the National Cancer Institute (Hopkins Technology, LLC). Therefore, there is a noteworthy health benefit for consuming 100% WW products. Moreover, 100% WW products are rich in B and E vitamins, iron, phytochemicals, and phytoestrogens. Published research on 100% WW tortillas is scarce. Thus, the purpose of this study was to investigate the effects of three selected emulsifiers on both the objective and subjective textural properties of tortillas made from 100% WW flour.

MATERIALS AND METHODS

Materials

One hundred percent WW flour (Hudson Cream, Hudson, KS) with 13.1% protein content was used to make tortillas. The flour did not contain any additives. The base formula for tortillas was outlined as follows: 6% vegetable shortening (Crisco, Orrville, OH), 1.5% salt (Primera Foods, Cameron, WI), 0.6% sodium bicarbonate (ADM, Decatur, IL), 0.58% sodium aluminum sulfate (Gallard-Schlesinger Industries, Plainview, NY), 0.5% sodium propionate (American Ingredients, Kansas City, MO), 0.4% potassium sorbate (American Ingredients, Kansas City, MO), and 0.24% encapsulated fumaric acid-BakeShure FT (Balchem Corp., New Hampton, NY). It was necessary to use such high levels of mold inhibitors, 0.9% total of sodium propionate and potassium sorbate, because microbial shelf life as well as the textural shelf life of tortillas were targeted to be preserved over the period of 20 days. Such levels of mold inhibitors may not viable commercially.

Three different emulsifying agents were studied as shelf life extenders: sodium stearoyl-2-lactylate (SSL), glyceryl monostearate (GMS 90), and deoiled soy lecithin (IP Pure 5251). SSL and GMS 90 were provided by Rita Corp. (Crystal Lake, IL), and IP Pure 5251 was provided by Northland Seed and Grain Corp. (St. Paul, MN). The amount of water added was based on the mixograph analysis indices (National Manufacturing Co., Lincoln, NE) of water absorption and dough development time. Ten units less of the mixograph water absorption value was used in the formulation. The high protein content of the flour corresponded to relatively high water absorption of the flour.

Dough Formation and Tortilla Processing

Dough was prepared according to the method of Bello et al (1991) with modifications. All dry ingredients were mixed with a bench-top mixer (Kitchen-Aid, model KSM-90, St. Joseph, MI) at low speed for 2 min. Shortening was added and mixing continued for 6 min more. Temperature of the distilled water was adjusted to 35°C and added slowly within 1 min. The dough was mixed for an additional 4 min at medium speed. It was rested for 10 min in a plastic container at 20°C and then divided and hand-rolled into 40-g balls. The dough balls were kept in a chamber at 35 ± 1°C and 70 ± 5% relative humidity for a resting period of 30 min.

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The dough balls were pressed using a tortilla dough press (Dual Heat DoughPro, Propress Corp., Paramount, CA). Top and bottom platens of the press were maintained at 80°C. Press time was 15 sec at thin setting. Metal strips of 1.5-mm thickness were placed on the left and right side of the bottom platen to prevent dough balls from overflattening. The tortillas were then baked on a griddle (DoughPro, model 1520) at 160°C for 35 sec, flipped, and cooked an additional 35 sec and then allowed to cool for 5 min on metal baking racks before packaging in plastic bags (Ziploc, S.C. Johnson & Son, Racine, WI). The tortillas were stored at 21 ± 1.5°C away from light.

Dough and Tortilla Characteristics

The dough pH was measured by using a pH meter (model IQ150, IQ Scientific Instruments, Carlsbad, CA) equipped with a surface probe. The moisture content of tortillas was measured by using Approved Method 44-15A (AACC International 2000). The pH of tortillas was determined by using Approved Method 02-52. The dough and tortilla pH and tortilla moisture are reported in Table I. The diameter of tortillas were measured after cooling, using a ruler at two diagonal points and averaged. A minimum of 20 tortillas were pressed for each batch. The mean of each batch of tortillas was taken as the representative average diameter for that batch.

Texture Measurements

The tortillas were analyzed at day 0, 2, 4, 8, 12, 16, and 20. A minimum of 10 subsamples were collected from each tortilla. Objective texture analyses on tortillas were performed using a texture analyzer (model TA.XT.Plus, Texture Technology Corp., Scarsdale, NY) and were based on the extensibility test used by Suhendro et al (1999) with modifications. An acrylic template was used to cut tortilla strips 37 mm long and 35 mm wide. A tensile grip probe was used with one grip attached to the moving arm and the other attached to the platform. Subsamples (tortilla strips from each tortilla) were kept in a sealed plastic bag, and measurements were taken immediately after cutting each tortilla into pieces. Extensibility tests used a trigger force of 0.05 N and pre- and post-test speed of 1 mm/sec to a 10-mm maximum distance. The rupture force (F_r), distance to tear (distance at F_r), and initial gradient (modulus of deformation) were either measured or calculated from collected force-distance data.

Subjective tortilla analyses were conducted using the rollability technique proposed by Friend et al (1995). Tortillas were wrapped around a wooden dowel 1.2 cm in diameter and evaluated on a continuous scale of 1 (impossible to roll due to breakage) to 5 (no cracking or breaking).

Experimental Design and Statistical Analysis

A completely randomized design (CRD) with two replicates was used. One-way analysis of variance (ANOVA) was used to analyze the data. Duncan's multiple range test at $\alpha = 0.05$ was used to identify significant differences in the means of measured parameters. All statistical analysis was carried out using SAS statistical software package (v. 8e, SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

Diameter

Addition of SSL at mid level and high level (0.25 and 0.5%), respectively, produced tortillas of significantly smaller diameter (Table II). This can be attributed to dough-strengthening properties of SSL, which yielded a highly elastic dough. Elasticity can be defined as the ability of dough to return to its original form once the force is removed (Wang and Flores 1999). SSL-added doughs were more elastic with shrink-back characteristics after pressing.

Distance at F_r (Stretchability)

Regardless of the type of the emulsifier added, the levels of each emulsifier produced a greater effect on the stretchability of fresh tortillas on day 0. The distance at F_r obtained from the uniaxial extensibility tests revealed that the lecithin at mid level (1%) and the control exhibited the lowest and highest values, respectively (Table II). Stretchability of low SSL (0.125%) tortillas was significantly higher than those containing mid (0.25%) and high (0.50%) levels of SSL. There were no significant differences in the means of different levels of GMS-added tortillas. Stretchability values of fresh tortillas with lecithin at low (0.5%) and high (2%) levels were significantly different than that of fresh tortillas with lecithin at the 1% level.

Stretchability of all the tortillas decreased with age. This is in close agreement with the previously reported research (Kelekci et al 2003; Adams and Waniska 2005; Bejosano et al 2005). At least 50% of the stretchability, as measured by distance at F_r, decreased by day 2. After day 4, there were no noteworthy changes in stretchability for all tortillas (Fig. 1). After day 8, the decline leveled off, indicating that loss in tortilla stretchability was maintained until the end of the storage duration of 20 days.

Rollability

All tortillas were rated from 1 (easily breakable) to 5 (easily rollable without cracking or breaking). Fresh tortillas (day 0) received a perfect 5 score. Rollability of all tortillas decreased over time (Fig. 2). At the end of day 20, lecithin at 2% and GMS at 1% yielded the highest rollability score of 3.5. The widely used level of SSL in flour tortillas is 0.25–0.5% (Suhendro et al 1993, 1995; Wang and Flores 1999; Cepeda et al 2000; Adams and Waniska 2002; Waniska et al 2002; Kelekci et al 2003; Bejosano and Waniska 2004; Bejosano 2005); 0.5% is the highest allowable limit in the United States but it may not be optimal in WW flour tortillas. Our findings indicated that within the SSL-added group, the lowest level (0.125%) was more effective than the mid (0.25%) and high (0.5%) SSL levels. Within the GMS-added

TABLE I
Dough pH, Tortilla pH, and Tortilla Moisture

	Dough pH	Tortilla pH	Tortilla Moisture (%)
Control	6.43	5.82	34.4
SSL, 0.125%	6.36	5.96	34.7
SSL, 0.25%	6.26	5.89	34.7
SSL, 0.5%	6.13	5.81	35.0
GMS, 0.5%	6.45	5.94	35.1
GMS, 1%	6.38	5.83	35.2
GMS, 2%	6.10	5.84	35.5
Lecithin, 0.5%	6.38	5.88	35.2
Lecithin, 1%	6.30	6.05	34.7
Lecithin, 2%	6.21	5.91	34.3
SD (n = 3)	0.12	0.07	0.38

TABLE II
Average Diameter and Distance at Stretchability (F_r) of Tortillas on Day 0[a]

	Tortilla Diameter (cm)	Distance at F_r (mm)
Control	16.4a	2.5a
SSL, 0.125%	16.4a	2.2a–c
SSL, 0.25%	15.9b	2.0d,e
SSL, 0.5%	15.8b	2.0d,e
GMS, 0.5%	16.5a	2.3a–c
GMS, 1%	16.3a	2.0c–e
GMS, 2%	16.4a	2.1b–e
Lecithin, 0.5%	16.3a	2.4a,b
Lecithin, 1%	16.3a	1.9e
Lecithin, 2%	16.4a	2.2a–d

[a] Mean values within a column with the same letter are not significantly different ($P < 0.05$).

group, the mid level (1%) was more effective than the low (0.5%) and high (2%) levels of GMS. Within the lecithin-added group, the highest level (2%) was most effective. Although the stretchability of tortillas reached its minimum by day 8, the rollability scores were still fairly high at 3.5–4. This indicates that loss in stretchability in tortillas with time is just one aspect of staling. Even though there was considerable decline in stretchability, the tortillas stayed acceptable, with minimal cracking when rolled on day 8. Stretchability of all emulsifier-added tortillas was lower than that of controls at day 0. The data demonstrate that initial rollability was not affected but loss in rollability was slower in most treated tortillas than in the controls. Tortilla stretchability dropped at day 2 and was relatively unchanged throughout the duration of the experiment; however, minimal changes in rollability were observed at this time and the rate of change in rollability was observed to be dependent upon the emulsifier concentration.

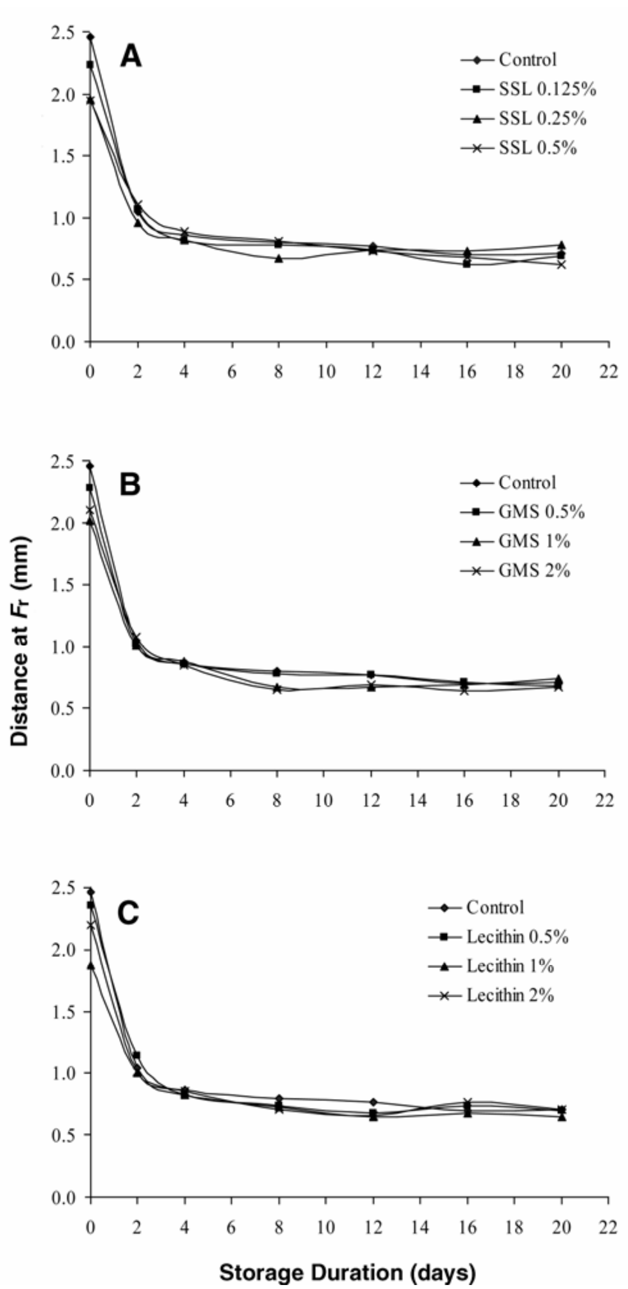

Fig. 1. Stretchability (distance to F_r) of whole wheat tortillas made with different concentrations of emulsifiers. **A**, sodium stearoyl lactylate (SSL) added; **B**, glyceryl monostearate (GMS) added; **C,** lecithin added.

Rupture Force (F_r)

Among the fresh tortillas (day 0), high-lecithin (2%) tortillas produced the lowest F_r (4.8 N). At the end of day 20, control tortillas consistently yielded the highest F_r (Fig. 3), along with lowest rollability score (Fig. 2). These results show that the additives had a positive effect on texture and prolonged shelf life. Moreover, when F_r was plotted as a function of storage duration (not shown), the slope of control tortillas showed a steeper response than the emulsifier-added tortillas. This fast-declining slope of control tortillas can also be identified in Fig. 1. This suggests that emulsifier addition influenced the rate of change of F_r as well as the stretchability and rollability of the tortillas.

CONCLUSIONS

All three emulsifiers tested (SSL, GMS, de-oiled lecithin) affected the textural quality of 100% WW tortillas during storage. However, the amount of emulsifier incorporated into the formulation was crucial. SSL was more effective at its lowest usage

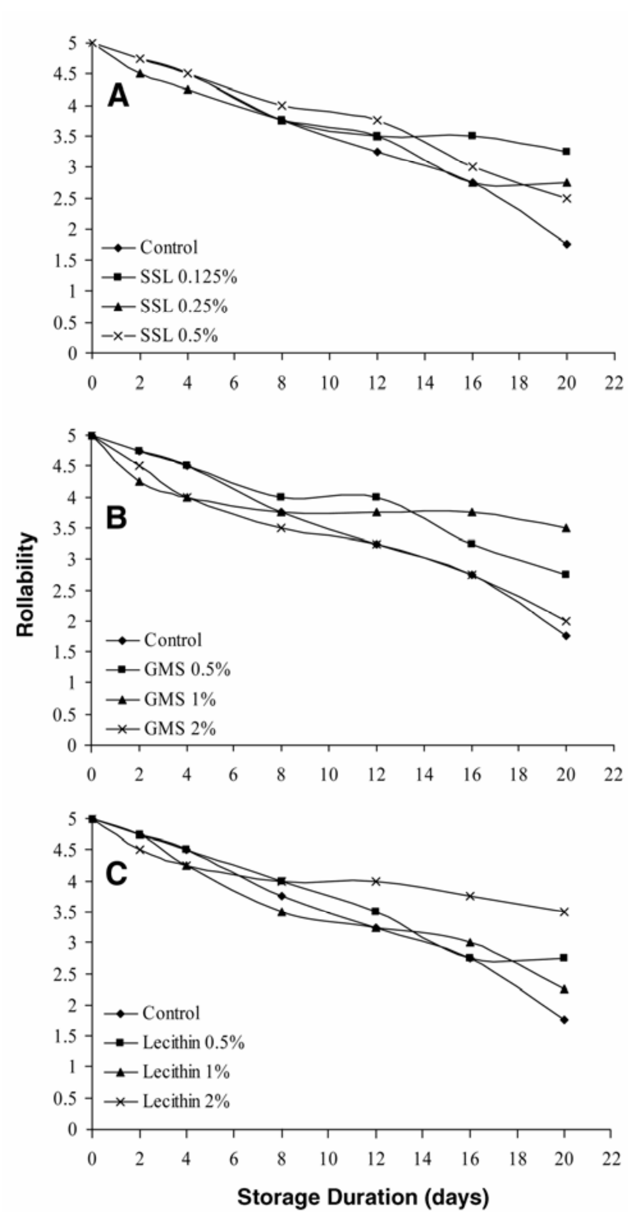

Fig. 2. Rollability scores of whole wheat tortillas made with different concentrations of emulsifiers. **A**, sodium stearoyl lactylate (SSL) added; **B**, glyceryl monostearate (GMS) added; **C**, lecithin added. Continuous scale of 1 (impossible to roll due to breakage) to 5 (no cracking or breaking).

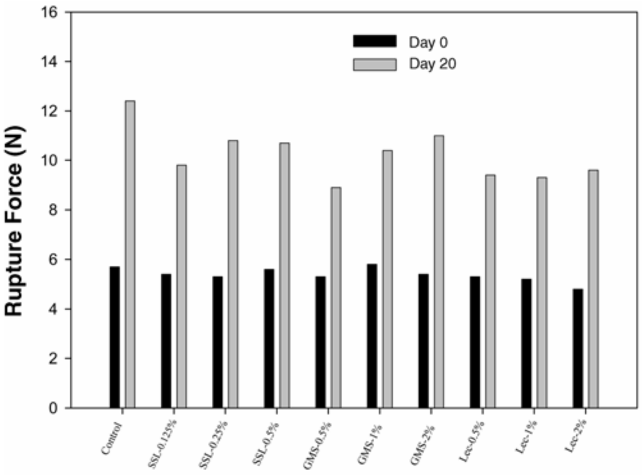

Fig. 3. Rupture force of whole wheat tortillas made with different concentrations of emulsifiers at day 0 and day 20; overall SD 0.76.

level (0.125%), unlike the de-oiled lecithin, which was most effective at its highest usage level (2%). The diameters of tortillas with mid (0.25%) and high (0.50%) levels of added SSL were significantly smaller than the rest of the tortillas. Rollability scores and F_r of tortillas were improved with emulsifier addition. Control tortillas consistently resulted in higher F_r values as well as lowest rollability scores at the end of full storage. None of the emulsifiers studied enhanced the stretchability of tortillas, as it abruptly declined during the first two days of storage. Type and level of emulsifier addition to tortillas should be determined carefully as it influences textural properties besides shelf life.

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