

# Potential of Triticale as a Substitute for Wheat in Flour Tortilla Production<sup>1</sup>

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## ABSTRACT

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The potential of triticale as a partial or total substitute for wheat in flour tortilla production was evaluated. Different mixtures of triticale and wheat flours were tested in a typical hot-press formulation. Both grains yielded similar amounts of flour. Wheat flour contained 1.5% more crude protein, 1.6× more gluten, and produced stronger dough than triticale. Triticale flour significantly reduced optimum water absorption and mix time of blends. Flour tortillas with 100% triticale absorbed 8% less water and required 25% of the mix time of the control wheat flour tortilla. The yield of triticale tortillas was lower than the rest of the tortillas due to lower moisture content and water absorption. Triticale dough balls required less proofing and ruptured during hot pressing, thus producing defective tortillas. The 50:50 flour mixture produced doughs with accep-

table rheological properties and good quality tortillas. Addition of 1% vital gluten to the 75:25 triticale-wheat flour mix or 2% to the 100% triticale flour significantly increased water absorption and mix time and improved dough properties and tortilla yields. Textural studies indicated that increasing levels of triticale flour reduced the force required to rupture tortillas. For all tortilla systems, rupture force gradually increased, and extensibility decreased during seven days of storage at room temperature; the highest rate of change occurred during the first day. Sensory evaluation tests indicated that triticale could substitute for 50% of wheat flour without affecting texture, color, flavor, and overall acceptability of tortillas. For production of 100% triticale flour tortillas, at least 2% vital gluten had to be added to the formulation.

The introduction of wheat by the Spaniards to the Americas led to the preparation of wheat flour tortillas. A flour tortilla can be defined as a chemically leavened, round flat bread produced from a gluten-structured dough. In 2000, U.S. sales at wholesale prices totaled more than \$4 billion, representing a growth rate of 57% over the past four years. Tortillas are the second highest selling product in the packaged bread category, surpassing even the highly popular bagels, croissants, English muffins, pita bread, and all other ethnic breads (Dally and Navarro 1999). The average American consumer prefers wheat flour tortillas to corn tortillas by a margin of two to one. Americans consumed more than 4.5 billion pounds of wheat flour tortillas, which is equivalent to ≈70 billion 1-oz units or 0.67 tortillas per American each day (Anonymous 2002). Most flours for tortillas are milled from hard red winter wheat, bleached, and enriched with B vitamins, iron, and zinc.

Triticale (*Triticosecale* Wittmack) is the first man-made cereal produced by crossing wheat (*Triticum* spp.) and rye (*Secale cereale* L.). The future of this crop is bright because it is environmentally more flexible than other cereals and shows better tolerance to diseases, drought, and pests than its parental species (Darvey et al 2000). Triticale world production has steadily increased during the past 20 years. Global production in 1980, 1990, and 2000 was estimated in 1.29, 5.44, and 9.6 million metric tons, respectively. Interestingly, average yields improved from 1980 to 2002 from 2.02 to 3.5 tons/Ha. In 2002, 3 million hectares were harvested, yielding a total production of 10.3 million metric tons (FAO 2003). Triticale has better nutritional qualities than wheat and better baking qualities than rye. Baking quality is inferior to wheat because it produces a weaker dough structure (Tsen et al 1973). According to Unrau and Jenkins (1964), triticale flour develops faster, absorbs less water, and has less stability than wheat flour dough.

In Mexico, wheat production has steadily decreased because the crop is usually irrigated and production costs are high. Triticale is planted because of its drought resistance and potential for production of both forage and grain. The price of triticale is lower than wheat.

The objectives of this study were to study the potential of triticale as a partial or total substitute for wheat in flour tortilla production and to study the effects of added vital gluten on the quality of triticale-rich tortillas.

## MATERIALS AND METHODS

### Grain Samples

A commercial composite sample of hard red winter wheat was utilized to obtain flour and tortillas. The triticale utilized was a selection from the Juanillo 86 cultivar (DRIDA/KISS/ARM S) originally produced by CIMMyT and adapted to northern Mexico. The cultivar was planted under irrigation and harvested at the ITESM-Campus Monterrey, experimental field located in Apodaca, Nuevo Leon, Mexico. The plant had a cycle of 120–125 days, an average height of 120–130 cm, and yielded 3.2 ton/Ha. The grain had a hectoliter weight of 77 kg/hL. Grains were tested for test weight, density, 1,000 kernel weight, and hardness. Test weight, expressed in kg/hL, was measured with a Winchester bushel meter (Seedburo Equipment Co., Chicago IL) according to Official US Grain Standard Procedures. Density was determined using a nitrogen comparison multipycnometer (model 90 Beckman Instruments, Fullerton CA). Thousand kernel weight was determined by weighing 100 randomly selected whole kernels. Grain hardness was measured by the Single Kernel Hardness Tester (Perten SK CS 4100), which categorizes wheat as soft, hard, or mixed. Hardness index was calculated using an algorithm developed by the USDA/ARS/US Grain Marketing Research Laboratory.

### Milling

Triticale and wheat, previously tempered to 15% moisture for 16 hr, were milled into refined flour using a Chopin roller mill (Moulin CD 1, Villeneuve La Garenne, France). cleaned grain samples (500 g) were subjected to one pass through break rolls and bran (+35 U.S. mesh sieve), middlings (–35 to +100 U.S. mesh sieves) and break flour (–100 U.S. mesh sieve) fractions were collected. The bran was manually sieved through a 35-mesh sieve, and throughs were collected and incorporated into the middlings. Middlings were sequentially ground five times through the reduction system (smooth rolls) and the resulting flours were collected. The straight-grade flour consisted of all flours collected during the milling process. Flour color was determined with a Minolta color meter (model CR-300, Minolta Camera Co., Osaka, Japan). Values for  $L$ ,  $a$ , and  $b$  were obtained, and color index  $E$  was determined by the equation  $E = (L^2 + a^2 + b^2)^{1/2}$ .

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## Treatments

Seven different tortilla systems were prepared and compared: 1) 100% wheat flour (positive control); 2) 75% wheat flour + 25% triticale flour; 3) 50% wheat flour + 50% triticale flour; 4) 25% wheat flour + 75% triticale flour; 5) 100% triticale flour (negative control); 6) 25% wheat flour + 75% triticale flour + 1% vital gluten; and 7) 100% triticale flour + 2% vital gluten.

## Tortilla Processing

**Tortilla formulation.** The basic formula included 1,000 g of flour, 120 g of vegetable shortening (Inca, Unilever de Mexico S.A de C.V., Tultitlán, Edo. de Mexico, Mexico), 15 g of refined iodinated salt (La Fina, Sales del Istmo, Coatzacoalcos, Ver., Mexico), 17 g of double-acting baking powder (Royal, Nabisco S.A. de C.V., Guadalupe, N.L., Mexico), 10 g of whole dry milk (Tecno Especialidades Comerciales S.A. de C.V., Monterrey, N.L. Mexico), 2 g of potassium sorbate (Pfizer, New York) and 2.8 g of fumaric acid (Denka Chemical, Houston, TX). Fumaric acid was added to achieve pH 5.9 for dough. Treatments 6 and 7 contained 1 and 2% wheat vital gluten (Midwest Grain Products, Atchison, KS), respectively.

**Preliminary tortilla trial.** Tortillas were prepared using methods of Bello et al (1991) with slight modifications. Flour (200 g, 14% mb), plus the ingredients listed above, was mixed with a predetermined volume of warm water (50°C) in a 100–200 g dough mixer (National Manufacturing Co., Lincoln, NE). Optimum water absorption and mix times were subjectively determined by observing dough properties. After 10 min of resting in a proof cabinet (National Manufacturing) at 29°C and 85% rh, the dough was divided into pieces  $25 \pm 0.25$  g, hand-rounded, and allowed to rest in the proof chamber for 20 min. Dough balls were hot-pressed into tortillas using an electric hot press (Tortilladora Electrica TH-10, Aidex S.A. de C.V., Guadalupe N.L., Mexico) operating at an average temperature of 100°C and then baked on an electric hot plate regulated at 210°C. The baking procedure consisted of baking for 20 sec on side 1, 30 sec on side 2, and 15 sec on side 1. The resulting tortillas were cooled for 20 min and placed in plastic bags.

**Commercial tortilla trial.** Tortillas were produced in a commercial tortilla factory. Formulations based on 2 kg of flour were optimally mixed with a predetermined volume of warm water (50°C) in a mixer (model A120T, Hobart Corp., Troy OH) equipped with a dough hook attachment. Upon water addition, contents were mixed at low speed for 1 min and then mixed at medium speed to attain optimum dough properties. Dough development times were subjectively determined by observing properties while mixing. The dough was divided into pieces  $20 \pm 0.25$  g, hand-rounded, placed on a tray, and allowed to rest for at least 20 min at room temperature. Dough balls were hot-pressed at 205°C, and

**TABLE I**  
Physical Properties of Wheat and Triticale<sup>a</sup>

	Test Wt (kg/hL)	Density (g/cm <sup>3</sup> )	Hardness/Classification	1,000 Kernel Weight (g)
Wheat	78.3 ± 0.2	1.40 ± 0.1	72/hard	32.5 ± 0.3
Triticale	79.0 ± 0.3	1.44 ± 0.1	46/mixed	37.2 ± 0.4

<sup>a</sup> Each value is the average of at least two observations.

**TABLE II**  
Proximate Composition of Wheat and Triticale Grains and Refined Flours<sup>a,b</sup>

Sample	Moisture (%)	Ash (%)	Protein (%N × 5.7)	Ether Extract (%)	Crude Fiber (%)	NFE <sup>c</sup> (%)
Whole grain						
Wheat	12.0 ± 0.2	1.47 ± 0.0	10.2 ± 0.4	2.2 ± 0.1	2.26 ± 0.2	71.9 ± 0.7
Triticale	10.6 ± 0.2	1.69 ± 0.0	9.7 ± 0.3	1.9 ± 0.1	2.16 ± 0.1	74.0 ± 0.6
Refined flour						
Wheat	11.3 ± 0.3	0.51 ± 0.0	9.5 ± 0.2	0.3 ± 0.1	0.02 ± 0.0	78.4 ± 0.6
Triticale	10.3 ± 0.2	0.62 ± 0.1	7.8 ± 0.2	0.8 ± 0.2	0.02 ± 0.0	80.5 ± 0.7

<sup>a</sup> Extraction rates for wheat and triticale were 54.3 and 56.3%, respectively.

<sup>b</sup> Each value is the average of at least two observations. Values are expressed on as-is basis.

<sup>c</sup> NFE = nitrogen-free extract.

baked in a four-stage gas-fired oven operating at an average temperature of 215°C (Torcal model 1100-220, Ramos Arizpe, Coahuila, Mexico). The average dwell time was 35 sec. Tortillas exiting the oven were cooled in a moving wire-mesh belt for 10 min and then placed on trays for 20 min before packaging in plastic bags. Tortilla weight and diameter were determined using 10 tortillas selected at random (Friend et al 1995).

## Gluten Content and Rheological Properties of Doughs and Tortillas

The gluten content of refined wheat and triticale flours was determined according to Approved Method 38-10 (AACC 2000).

Mixographs were obtained according to the procedure of Finney and Shogren (1972) using a 35-g mixograph (National Manufacturing Co., Lincoln NE). The falling number (model 1500, Perten Instruments North America, Reno NV) test was used to estimate enzyme activity of the flours according to Approved Method 56-81B (AACC 2000). The resistance of dough to stretching and elasticity was measured with an alveograph (Chopin NG-VO.07-97, Villeneuve la Garenne, France).

The measurement of dough extensibility was performed using the SMS/Kieffer Rig probe of a texture analyzer (model TA.XT2, Texture Technology Corp., Scarsdale, NY). Tests were performed after 40 min of dough relaxation according to the procedure described by Smewing (1995). Peak force, distance at peak force, and work (area under the curve) were obtained.

The texture of tortillas throughout seven days of storage was objectively evaluated according to the extensibility method proposed by Suhendro et al (1999). Tortilla strips (35 × 75 mm) were cut from the tortilla using an acrylic template, avoiding the puffed portions (to maintain sample uniformity). The ends of the strip were held by grips that were separated by 30 mm and extended at 1.0 mm/sec using the TA.XT2 texture analyzer. The rupture force, distance at peak force, and work during extension were measured.

**TABLE III**  
Color Scores, Alveograph, Mixograph, Gluten, and Falling Number Properties of Wheat and Triticale Flours<sup>a</sup>

	Wheat Flour	Triticale Flour
Falling Number, sec	320	62
Dry gluten content, %	13.79	8.51
Color		
<i>L</i>	71.50	74.07
<i>a</i>	0.07	-0.06
<i>b</i>	7.04	4.72
<i>E<sup>b</sup></i>	71.85	74.07
Mixograph		
Development, min	5.7	1.6
Stability	79	74
Decay	6	8
Alveograph		
<i>W</i> , 10 <sup>-4</sup> J/min	232	24.5
<i>P</i> , mm	82.7	20.1
<i>L</i> , mm	50	23
<i>P/L</i>	1.65	0.87

<sup>a</sup> Each value is the average of at least two observations.

<sup>b</sup> Color index *E* was determined by the equation  $E = (L^2 + a^2 + b^2)^{1/2}$ .

## Chemical Analysis of Grains, Flours and Tortillas

Grains, flours, and tortillas were characterized for moisture, crude protein, crude fat, crude fiber, and ash according to Approved Methods 44-15A, 46-13, 30-20, 32-10, and 08-01, respectively (AACC 2000). The caloric value of tortillas was calculated based on the amounts of nitrogen-free extract (NFE), protein, and ether extract using the equation  $DE = (\% \text{ NFE} \times 4 \text{ kcal/g}) + (\% \text{ protein} \times 4 \text{ kcal/g}) + (\% \text{ ether extract} \times 9 \text{ kcal/g})$ .

## Sensory Evaluation of Tortillas

For sensory evaluation, 49 untrained panelists evaluated the color, flavor, texture, and overall acceptability of tortillas produced from 100% wheat flour; 50% wheat flour plus 50% triticale flour; 25% wheat flour plus 75% triticale flour; and 100 triticale flour plus 2% vital gluten. Tortillas were evaluated using a nine-point hedonic scale as recommended by Anzaldúa-Morales (1994) where +4 = like extremely, 0 = neither like nor dislike, -4 dislike extremely. Panelists evaluated tortillas produced within 24 hr in individual booths in a sensory evaluation laboratory. Before evaluation, tortillas were cut into four pie-shaped pieces, reheated for 10 sec in a manual tortilla press at 100°C and stored in a closed container. Data were subjected to statistical analysis using JMP v. 4 computer software (SAS Institute, Cary, NC). Differences among means were compared using least significant difference ( $P < 0.05$ ).

## RESULTS AND DISCUSSION

### Grain and Flour Characteristics

Triticale had a higher test weight, density, and 1,000 kernel weight than wheat (Table I). According to Unrau and Jenkins (1964) and Darvey et al (2000), triticale grain is larger than both its parental species and has a higher kernel weight. Varughese et

al (1996a,b) reported that most triticale lines have test weight >77 kg/hL. The wheat was classified as hard red winter, whereas the triticale was classified as mixed or with intermediate hardness. Wheat had a higher protein content than triticale (Table II). Both types of kernels had excellent properties for milling and yielded similar amounts of refined flour after roll milling. The flour extraction rates for wheat and triticale were 54.3 and 56.3%, respectively. These experimental values are slightly higher than the ones reported by Darvey et al (2000). Refined flour from wheat contained 1.7% more protein, 0.1% less ash, and 0.5% less ether extract than triticale flour (Table II). According to Tsen et al (1973), Unrau and Jenkins (1964), and Darvey et al (2000), the protein content of triticale is usually higher than that of wheat. Darvey et al (2000) also found that six different triticale flours contained more ash than wheat flour (0.51 vs. 0.47%) (Table II).

Wheat flour (320 sec) had falling number five times higher than triticale flour (62 sec), indicating lower amylase activity (Table III). Leon et al (1996) found falling number values of 62–134 sec for 10 different triticale flours. Low values of falling numbers compare with rye characteristics and imply a high  $\alpha$ -amylase activity (Leon et al 1996; Darvey et al 2000).

Triticale flour contained considerably less gluten than wheat flour (Table III). The triticale gluten content is within the range reported by Leon et al (1996) for five triticales (6.7–10.2% dry gluten). Varughese et al (1996a,b) and Chen and Bushuk (1970) determined that triticale contained lower amounts of prolamins and glutelins than wheat flour. SDS studies conducted by Leon et al (1973) confirm that triticale contains less gluten than wheat.

The triticale mixograph curve indicated that the dough was softer and weaker than wheat (Table III). The triticale dough developed after 1.6 min of mixing in comparison to 5.7 min observed for wheat flour dough. The triticale dough developed readily with

TABLE IV  
Rheological Properties of Tortilla Doughs Produced from Wheat and Triticale Flours<sup>a</sup>

Dough Type			Peak Force (g)	Distance <sup>b</sup> (mm)	Area <sup>c</sup> (g × mm)
Wheat (%)	Triticale (%)	Vital Gluten (%)			
100	0	0	54.3	44.03	1,561
75	25	0	26.7	50.65	1,073
50	50	0	23.1	44.83	1,040
25	75	0	16.1	45.56	732
0	100	0	11.2	26.93	441
25	75	1	16.1	44.83	742
0	100	2	27.4	50.39	1,097

<sup>a</sup> Each value is the average of eight observations.

<sup>b</sup> Distance is a measurement of dough extensibility.

<sup>c</sup> Area is a measurement of work required to deform the dough.

TABLE V  
Optimized Process Parameters of Tortillas Produced from Wheat and Triticale Flours

	Tortilla Formula						
	1	2	3	4	5	6	7
Wheat flour, %	100	75	50	25	0	25	100
Triticale flour, %	0	25	50	75	100	75	0
Vital gluten, %	0	0	0	0	0	1	2
Preliminary tortilla trial							
Water absorption, %	50	48.7	47.5	44.3	42.0	45.8	44.0
Mix time, min:sec	4:08	4:00	2:50	2:15	1:45	2:25	1:45
Proof time, <sup>a</sup> min	15	10	10	5	0	10	5
Commercial tortilla trial							
Water absorption, %	50	48.7	47.5	44.3	42.0	45.8	44.0
Mix time, <sup>b</sup> min:sec	5:30	4:20	4:05	2:35	1:30	2:55	2:05
Tortilla diameter, mm	112.5	108.0	113.5	117.2	118.5	111.1	114.0
Tortilla wt/dough wt, %	93.0	92.7	91.9	91.3	89.5	92.2	91.7
Tortilla yield (tortilla wt/flour wt)	1.71	1.53	1.51	1.47	1.42	1.51	1.49
% Defective tortilla <sup>c</sup>	0	0	0	12.3	46.6	0	0

<sup>a</sup> Determined as minimum proof time to achieve maximum pressed tortilla diameter. Proof times determined in 5-min increments for a total of 20 min.

<sup>b</sup> Dry ingredients and water were first mixed 1 min at low speed before switching velocity to medium.

<sup>c</sup> Tortillas that ruptured during hot pressing.

a low stability and fast decay, indicating deficient gluten quantity and quality. Using a farinograph, Seguchi et al (1999) also determined that triticale absorbed less water, had a lower stability or dough mixing tolerance, and a weaker gluten than wheat. All alveograph parameters confirmed that wheat dough was stronger. In comparison with triticale flour, wheat had higher values (at least 9× for *W*, 4× for *P*, 2× for *L*; and 2× for *P/L*). The *P/L* value in wheat and triticale corresponds to hard and soft flours, respectively.

### Rheological Properties of Tortilla Doughs

Extensibility tests performed in optimized tortilla doughs indicated that the 100% wheat dough required 5× and 10× more peak force and work to deform the dough than the triticale dough (Table IV). Addition of triticale flour to wheat reduced peak force and work and significantly increased extensibility. The systems containing up to 50% triticale produced a more balanced force/extensibility behavior. Doughs containing 75 or 100% triticale had the lowest peak force and deformation work; the lack of these rheological properties could have caused the rupturing of tortillas during hot pressing (Table V). Tsen et al (1973) determined that high concentrations of triticale caused rupture of the weak dough structure during fermentation of wheat-triticale composite breads.

Addition of 50% triticale flour reduced peak force >50% and the work required to stretch the dough >33% due to the lower and weaker triticale gluten structure. Interestingly, the extensibility remained the same. The 100% triticale dough had 20 and 28% of the peak force and work obtained in the 100% wheat dough. That is the reason why most of these dough balls ruptured during hot pressing and produced defective tortillas. Addition of 1 and 2% vital gluten to the 75:25 triticale-wheat or 100% triticale systems increased peak force and work and therefore improved rheological properties and tortilla characteristics. The improvement was more evident in the 100% triticale flour supplemented with 2% vital gluten. Its dough had a peak force, extensibility, and work similar to the 75:25 wheat-triticale dough and produced 0% defective tortillas.

### Flour Tortilla Characteristics

The wheat flour tortilla dough absorbed the water commonly added to tortilla formulations (Serna Saldivar et al 1988; Bello et al 1991; Friend et al 1992). Addition of increasing levels of triticale flour significantly decreased mix time and water absorption (Table V). Seghuchi et al (1999) found similar trends when wheat-triticale blends were processed into table bread. The 100% triticale dough absorbed ≈8% less water than the wheat dough due to its lower gluten content. Tsen et al (1973) working with triticale and wheat flours for bread found that triticale dough systems developed faster with a substantially lower absorption and shorter stability, and attributed these effects to the lower and weaker gluten. As a result of the lower water absorption, the triticale flour yielded ≈17% fewer tortillas than wheat flour, and the tortillas contained less moisture (Table V). Addition of vital

gluten to the triticale flour increased dough development time, water absorption, and tortilla yield. For every 1% vital gluten addition, the absorption increased 1%.

As triticale increased in the tortilla mix, the dough required shorter proof times to achieve optimum properties for hot pressing. The proof time in commercial operations is generally 15–20 min. In fact, the 100% triticale dough balls did not require any proofing because they yielded tortilla disks with diameters similar to counterparts processed from balls rested for 20 min (Table V). In the industry, it is recognized that the flour protein content is closely related to proofing requirements and, in some instances, reducing agents are utilized to shorten times. Dough balls containing 75 or 100% triticale tended to rupture during hot pressing, thus producing defective tortillas. The effect was more obvious in the 100% triticale formulation. The triticale flour did not contribute enough to create an appropriate gluten network needed for tortilla production. Addition of 1 and 2% vital gluten to the 75 and 100% triticale blends, respectively, counteracted this negative effect and improved dough machinability and tortilla quality (Table V).

### Chemical Composition of Tortillas

Flour tortillas had a chemical composition and calorie values similar to those reported by other authors (Saldana and Brown 1984; Gonzalez Agramon and Serna Saldivar 1988; Serna Saldivar and Rooney 2003;). Caloric density of tortillas mainly depends on the level of shortening in the formulation and the tortilla moisture content. A 100-g serving of these tortillas provided ≈300 kcal. Addition of increasing levels of triticale decreased tortilla moisture and protein contents and produced more energy-dense tortillas (Table VI).

### Tortilla Texture Throughout Storage

For all systems, the best textural properties were observed in fresh tortillas (Table VII). These tortillas required the lowest rupture force and showed the highest distance of extension, a measurement of flexibility. Addition of higher levels of triticale reduced the force required to rupture tortillas, distance of extension, and work. The 100% triticale tortilla had the lowest values. Most of the textural changes in tortillas occurred after one day of storage. These tortillas required 1.3× to 1.4× more rupture force and decreased their extensibility ≈40–50%. Tortillas stored for longer periods of time continued to lose these textural properties. After one week of storage, the rupture force of tortillas at least doubled, and the extensibility decreased to ≈33% of the original value. Addition of vital gluten to triticale-rich tortillas improved the rupture force-to-distance of extension ratio and therefore counteracted the negative effects of the triticale flour.

### Sensory Properties of Tortillas

Panelists liked all tortillas tested (Table VIII). The flavor, texture, color, and overall acceptability of the tortillas containing 25 and 50% triticale ranked higher than the control wheat tortilla and triticale tortilla supplemented with vital gluten. Addition of

TABLE VI  
Proximate Composition and Estimated Caloric Value of Tortillas Produced from Wheat and Triticale Flours<sup>a</sup>

Tortilla Formula			Moisture (%)	Ash (%)	Crude Protein <sup>b</sup> (%)	Crude Fat (%)	NFE <sup>c</sup> (%)	Calories (kcal/100 g)
Wheat (%)	Triticale (%)	Vital Gluten (%)						
100	0	0	31.1 ± 0.5	2.0 ± 0.0	7.75 ± 0.4	6.6 ± 0.6	52.6 ± 1.5	300.6 ± 1.0
75	25	0	31.5 ± 0.6	2.0 ± 0.1	7.02 ± 0.3	7.7 ± 0.5	51.8 ± 1.5	304.5 ± 0.3
50	50	0	31.0 ± 0.5	2.0 ± 0.1	7.02 ± 0.4	8.0 ± 0.3	52.0 ± 1.3	308.0 ± 0.9
25	75	0	28.8 ± 0.7	2.2 ± 0.1	7.30 ± 0.3	7.8 ± 0.4	53.9 ± 1.5	315.0 ± 1.2
0	100	0	25.5 ± 0.6	2.2 ± 0.2	6.84 ± 0.3	7.5 ± 0.5	58.0 ± 1.6	326.9 ± 0.7
25	75	1	31.4 ± 0.3	2.3 ± 0.2	7.39 ± 0.4	7.0 ± 0.4	51.9 ± 1.3	300.2 ± 0.1
0	100	2	30.7 ± 0.5	2.3 ± 0.1	8.11 ± 0.3	6.8 ± 0.3	52.1 ± 1.3	302.0 ± 0.9

<sup>a</sup> Each value is the average of at least two observations. Values are expressed on as-is basis. Crude fiber was not estimated because of the use of refined flours.

<sup>b</sup> Determined as N × 5.7.

<sup>c</sup> NFE = nitrogen-free extract.

**TABLE VII**  
Textural Properties of Tortillas Produced from Wheat and Triticale Flours Stored for Seven Days<sup>a</sup>

Tortilla Formula			Days of Storage	Rupture Force <sup>b</sup> (g)	Distance of Extension <sup>c</sup> (mm)	Area <sup>d</sup> (g × mm)
Wheat (%)	Triticale (%)	Vital Gluten (%)				
100	0	0	0	455 ± 9.7	6.30 ± 0.2	7,215 ± 19
			1	657 ± 13.8	3.18 ± 0.1	7,380 ± 20
			3	787 ± 15.4	2.09 ± 0.1	7,597 ± 22
75	25	0	7	1,012 ± 17.2	1.90 ± 0.1	7,027 ± 23
			0	462 ± 11.6	5.94 ± 0.3	6,685 ± 19
			1	673 ± 14.1	3.60 ± 0.2	7,201 ± 21
50	50	0	3	773 ± 16.3	1.84 ± 0.1	4,928 ± 17
			7	911 ± 16.6	1.38 ± 0.1	4,868 ± 19
			0	466 ± 8.7	5.53 ± 0.2	5,937 ± 17
25	75	0	1	632 ± 9.4	3.15 ± 0.2	6,480 ± 22
			3	779 ± 13.6	2.04 ± 0.1	4,907 ± 16
			7	993 ± 14.1	1.55 ± 0.1	5,509 ± 19
0	100	0	0	406 ± 11.4	5.59 ± 0.2	4,858 ± 19
			1	526 ± 17.4	3.40 ± 0.2	5,546 ± 23
			3	734 ± 18.3	1.70 ± 0.1	4,390 ± 17
25	75	1	7	978 ± 18.9	1.52 ± 0.1	5,267 ± 21
			0	338 ± 8.1	3.90 ± 0.3	4,510 ± 20
			1	446 ± 13.7	2.25 ± 0.2	4,825 ± 22
0	100	2	3	538 ± 13.8	0.87 ± 0.1	3,161 ± 19
			7	737 ± 18.4	0.87 ± 0.1	3,748 ± 19
			0	400 ± 10.5	7.57 ± 0.4	7,486 ± 27
25	75	1	1	530 ± 11.9	5.90 ± 0.2	7,352 ± 25
			3	829 ± 12.4	2.29 ± 0.1	4,755 ± 21
			7	1,408 ± 13.9	1.62 ± 0.1	5,412 ± 22
0	100	2	0	296 ± 7.4	4.66 ± 0.2	4,002 ± 19
			1	445 ± 9.9	2.93 ± 0.1	5,295 ± 18
			3	553 ± 11.2	1.73 ± 0.2	3,687 ± 17
			7	591 ± 10.8	1.38 ± 0.1	3,500 ± 16

<sup>a</sup> Each value is the average of six observations.

<sup>b</sup> Rupture force is a measurement of tortilla firmness.

<sup>c</sup> Distance is a measurement of tortilla extensibility.

<sup>d</sup> Area is a measurement of work required to rupture the tortilla.

**TABLE VIII**  
Comparison of Sensory Properties of Tortillas Produced from Wheat and Triticale Flours<sup>a</sup>

Tortilla Formula			Color	Flavor	Texture	Acceptability
Wheat (%)	Triticale (%)	Vital Gluten (%)				
100	0	0	1.76a	1.76ab	1.63ab	1.96b
50	50	0	2.35b	1.58a	1.82ab	2.03b
25	75	0	2.54b	2.31b	2.15b	2.33b
0	100	2	1.29a	1.23a	1.31a	1.31a

<sup>a</sup> Using 9-point hedonic scale (+4 = like extremely, 0 neither like nor dislike; -4 dislike extremely). Each value is the average of 49 observations. Values followed by the same letter in the same column are not significantly different ( $P < 0.05$ ).

increasing levels of triticale to wheat flour produced lighter tortillas because the triticale flour was lighter than wheat flour (Table III). The wheat flour tortilla had opaque and translucent spots, whereas the triticale tortillas had a homogenous opacity. According to Adams et al (2001), the tortilla opacity greatly affects appearance and can be controlled by the type and concentration of leavening acids and dough pH. Interestingly, panelists preferred the texture of tortillas containing 25 or 50% triticale to the control wheat tortillas ( $P < 0.05$ ). The sensory evaluation data demonstrated that addition of 25 or 50% triticale to the wheat flour tortilla did not produce the adverse effects as in other types of bakery products such as table bread. On the contrary, these levels of triticale addition produced tortillas with better organoleptic properties and overall acceptability than the control wheat tortillas.

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