Objective Texture Measurements of Commercial Wheat Flour Tortillas[1]

Yufeng Mao,[2] Rolando A. Flores,[3,4] and Thomas M. Loughin[5]

ABSTRACT

Cereal Chem. 79(5):648–653

Texture is a property of major importance in the evaluation of baked products. To determine a sample of commercial ranges for stretchability, rollability, firmness, and Kramer shear cell measurements for wheat flour tortillas using the TA-XT2 texture analyzer, three separate sets of five tortilla brands purchased from stores in Manhattan, KS, were evaluated. Two brands had two formulations, regular and fat-free. Significant differences ($P < 0.05$) in stretchability, firmness, and Kramer shear cell occurred between regular and fat-free tortillas of one tortilla brand. Significant differences ($P < 0.05$) also were found among the sets of some tortilla brands. Kramer shear cell and stretchability measurements are recommended because Kramer shear cell measures the force combined with compression, shearing, and extrusion. Stretchability measurements were repeatable and are an important textural property of wheat flour tortillas. Ranges for textural properties for commercial wheat flour tortillas were determined, as well as the variability of the textural methods used.

The textural properties of a food are defined as a group of physical characteristics that arise from its structural elements, that are perceived by the sense of touch, and that are related to the deformation, disintegration, and a flow of the food under a force (Bourne 1982). Szczesniak et al (1963) described the relationships between the textural parameters of food and the popular terms that are used to describe these properties. Food texture as represented by the terms soft, firm, or hard was described as a textural parameter; the degree of hardness and texture represented by the terms tender, chewy, or tough were described as chewiness.

Wheat flour tortilla texture can be measured subjectively or objectively (Wang and Flores 1999). For the subjective measurements, a group of trained panelists is required. However, this method is not sensitive enough to monitor changes in tortilla texture within 24 hr of baking (Yau et al 1994). The objective measurements are designed for the imitation and development of subjective measurements, and involve certain equipment such as a universal testing machine. The objective method is quantitative, sensitive, fast, and repeatable compared with subjective methods (Suhendro et al 1999).

Subjective measurement of tortilla texture includes rollability and flexibility techniques. A tortilla is wrapped and rolled around a 1-cm diameter wood dowel, and the rollability is recorded by a trained panel on a scale of 1 to 5 (1 = unrollable [worst]; 5 = no cracking [best]). A tortilla is squeezed by hand to evaluate the overall flexibility (i.e., firmness, squeezability, and breakability), and is rated on a scale of 1 to 5 (1 = extremely firm, rigid, and inflexible [worst]; 5 = extremely soft and flexible [best]) (Suhendro et al 1999).

Objective texture measurement is used widely for the evaluation of baked products. Baker and Ponte (1987a,b), Baker et al (1988), and Redlinger et al (1985) reported bread firmness measured by an Instron Universal Testing (IUT) machine. Walker et al (1987) used it to determine cake firmness. Bedolia et al (1983) measured the firmness of corn tortillas with sorghum using an IUT machine with a Kramer shear cell (KSC): a tortilla strip 5 × 10 cm^2 was placed into the KSC and sheared at a constant crosshead speed; texture was expressed as maximum shear force (N). They reported that the coefficient of variation for the method was 9.8%. Twillman and White (1988) measured the firmness of corn tortillas using the IUT with an Ag Canada multiblade shear cell; firmness was expressed as peak force (kg). The correlation between the peak force and sensory evaluation of firmness was poor ($r = 0.15$, $P < 0.05$). Torres et al (1993) used the IUT machine with a punch and die testing cell to determine the firmness of tortillas. A tortilla disk was penetrated and punctured by a solid stainless steel rod with a flat end; firmness value was expressed as the area (Nm) under the force-deformation curve. A correlation between sensory evaluation and instrumental measurement of firmness was observed ($r = 0.82$, $P < 0.05$) (Torres et al 1993).

Arámbula et al (1998) measured firmness of corn tortillas using the TA-XT2 texture analyzer with a TA-96 probe to determine tensile strength and with a TA-90 probe to determine cutting force. A tortilla strip of 3.7 × 9 cm was stretched and cut, and the firmness of a corn tortilla was expressed as the peak force (kg_f) required to break and cut the strip. Wang and Flores (1999) measured the firmness of flour tortillas using the TA-XT2 texture analyzer with a TA-108 probe in the compression force mode. They also measured the stretchability of flour tortillas using the same apparatus with tortilla fixture. The TA-XT2 texture analyzer was used to conduct a bending test of corn tortillas (Suhendro et al 1998a) and also was used with a custom-designed rollability fixture to measure the rollability of corn tortillas and with TA-96 double clamp to determine the extensibility of corn tortillas (Suhendro et al 1998b).

A good quality tortilla should be less firm, have good flexibility, and have good rollability. Research reports on measurements of commercial tortilla texture are relatively few, and no commercial ranges for the textural parameters have been reported. Analysis of tortilla texture is needed because it is such an important quality attribute recognized by the customer. Therefore, this study 1) examined the stretchability, Kramer shear cell measurement, firmness, and rollability of commercial flour tortillas using the TA-XT2 Texture Analyzer; 2) evaluated the application of those methods to commercial tortilla texture resulting from different formulations and different sets; and 3) determined the ranges of the textural properties of commercial tortillas.

MATERIALS AND METHODS

Tortilla Samples

Five brands of commercial baked flour tortillas, of which two brands had both a regular and fat-free formulation, were purchased in Manhattan, KS. The samples were labeled ID#1 to ID#7. The five

---

[1] Contribution No. 01-36-J of the Kansas State University Agricultural Experiment Station, Manhattan, KS.

[2] Graduate research assistant, Department of Grain Science and Industry, Kansas State University, Manhattan, KS 66506.

[3] Formerly with the Department of Grain Science and Industry, Kansas State University, Manhattan, KS. Currently with the USDA-ARS Eastern Regional Research Center, Microbial Food Safety Research Unit, Wyndmoor, PA 19038. Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by the USDA implies no approval of the product to the exclusion of others that may also be suitable.

[4] Corresponding author. Fax: 215-233-6559. Phone: 215-233-6489. E-mail: rflores@arserrc.gov.

[5] Associate professor. Department of Statistics, Kansas State University, Manhattan, KS 66506.

Publication no. C-2002-0802-02R.

brands were purchased on three different random occasions within a period of 21 weeks, now on referred as sets 1, 2, and 3. The tortillas were purchased immediately after they were placed on the shelf for sale. Within a brand each set had different consumption due dates.

Tortilla Physical Characteristics

The moisture content of the tortillas was determined using the two-stage Approved Method 44-15A (AACC 2000). The diameter of the tortillas was the average of two perpendicular lines on each of three tortillas, and the weight of tortillas was the average of three tortillas. Tortilla color was determined for three tortillas, with three repetitions each using a chromameter (CR-300, Minolta) with a standard calibration plate (CR-A44). The thickness of the tortillas was determined during the firmness measurement using the TX-T2 texture analyzer (Stable Micro Systems, Texture Technologies Corp. Scarsdale, NY).

Tortilla Image Analysis

The SPX Speck Expert digital image analyzer (SPX, Maztech Micro Vision Ltd., Ontario, Canada), originally developed for speck counting in semolina, was used to analyze the tortilla image for the determination of the toast spot area. The SPX Speck Expert counts black and brown specks over a range of gray levels from 0 (black) to 255 (white) (Kim and Flores 1999). The SPX Speck Expert is driven by Maztech's Scan ProXpert software that acquires, analyzes, and enumerates specks by gray level and particle size. A global level of 120 and particle size of 1,000–9,000 µm were selected. If the speck was >9,000 µm, then it was counted as an oversized speck, which was shown in yellow overlays. To easily extend the sample size, the holder portion of the SPX was removed, the glass was covered with commercial food wrap film and a tortilla was put directly on the glass of the scanner. The range of interest (ROI) was adjusted to 8 in. for width and height with an offset of 0.02 and a resolution of 450 dpi. Results were imported into a spreadsheet as a formatted text file.

Objective Tortilla Textural Property Measurement

The stretchability, Kramer shear cell, firmness, and rollability of flour tortillas were measured using a TA-XT2 texture analyzer.

A TA-108 tortilla film fixture and a 3/4" rounded-end probe were used for the stretchability measurement. First, the probe was set to a distance of 60 mm from the analyzer arm to the platform. A tortilla was fixed onto the fixture and positioned with the double-baked side down. The probe traveled at 6.0 mm/sec until the tortilla's surface was detected at 0.2N force. The probe then traveled at 2.0 mm/sec for up to 30 mm, a distance chosen to stretch the tortilla until it thoroughly ruptured. The probe was withdrawn at 10.0 mm/sec. The force (N), the distance (mm) that compresses the tortilla until rupture, the area under the curve or work (Nmm), and the slope (N/mm), which was the ratio of force to distance on the force-distance curve, were recorded.

Kramer shear cell was measured using a TA-91 with five blades attached to a TA-XT2 texture analyzer. A tortilla sample was cut and placed over the bottom of the sample cell. Before the test was conducted, the blades were set to a distance of 95 mm from the analyzer arm to the platform. The force-deformation curve was recorded. The maximum force (N); the area or work (Nmm) under the curve, and the slope (N/mm), which was the ratio of force to distance on the straight line of the force-distance curve, were recorded.

The firmness measurement was made using the TA-XT2 texture analyzer with a 3/4" rounded-end probe, set to a distance of 10 mm from the analyzer arm to the platform. A tortilla was placed onto the flat platform with the double-baked side down. Measurements of the force-deformation curve were taken. The force (N), which was the amount required to compress the tortilla until 30% strain, the distance, the area or work (Nmm) under the curve; and the slope (N/mm), which was the ratio of force to distance on the straight line of the force-distance curve, were recorded. The distance (30% strain) was used to determine the thickness of the tortilla.

The TA-XT 2 texture analyzer with a rollability fixture (dowel 1.9 cm diameter) set on the base platform was used to measure tortilla rollability. The probe was set to a distance of 160 mm from the TA-XT 2 cross-arm to the platform. The tortilla edge was gripped fully by the metal rod, with the double-baked side of the tortilla facing down. The force and the area or work (Nmm) required to roll a tortilla one turn on the dowel were recorded. The peak force that occurred during the first turn was related to the ease of rolling the tortilla (Suhendro et al 1998a).

Experimental Design

The physical and textural properties of flour tortillas were evaluated using one-way analysis of variance (ANOVA) in a randomized complete block experimental design. Seven treatments (K = 7) included five brands of tortillas and two formulations of tortillas in two brands (ID#1 to ID#6). The three different sets (set 1 to set 3) of tortilla included three blocks (b = 3). Five subsamples of tortillas per treatment and block were used in the textural properties and three subsamples of tortillas in physical characteristics. All significant differences were at the 95% confidence level.

RESULTS AND DISCUSSION

Tortilla Physical Properties

The ranges of physical properties of the flour tortillas are shown in Table I. Comparing the moisture content of seven treatments showed that ID#4 had significantly higher moisture than the others. When the three sets of tortillas were compared for moisture content within each ID#, no significant moisture differences occurred among the three sets of tortillas for ID#1, ID#4, and ID#5. However, significant differences did occur between sets 1 and 2 and between sets 2 and 3 for ID#2, between sets 2 and 3 for ID#3, between sets 2 and 3 for ID#6, and between sets 2 and 3 and between sets 1 and 3 for ID#7.

A comparison of the toast spot areas (%) among the seven treatments of three sets of tortillas showed that ID#4 had signi-

TABLE I
Physical Properties of Commercial Flour Tortillas

ID#[a]	Moisture (%, wb)	Toast Spots[b] (%)	Color (*L* value)	Thickness (mm)	Weight (g)	Diameter (mm)
1*	30.79–31.78	0.30–3.34	81.34–83.93	1.27–1.72	27.83–30.03	16.08–16.25
2	31.32–32.41	0.03–4.88	80.91–83.22	1.42–1.64	27.13–29.77	15.80–16.53
3	32.37–33.57	1.23–5.56	82.40–83.07	1.62–1.85	34.23–49.53	17.57–20.88
4	34.16–36.96	3.88–18.15	79.37–80.66	2.24–2.45	65.67–69.72	19.70–21.10
5	29.62–30.95	1.38–1.69	82.56–84.73	1.03–1.18	36.70–37.97	20.27–20.33
6*	31.95–64.50	3.81–7.18	80.39–81.41	1.54–1.92	33.63–34.90	15.55–16.80
7	31.92–33.97	3.96–4.68	81.30–82.02	1.69–2.37	33.00–37.57	15.50–16.50

[a] * Indicates fat-free tortillas.

[b] Percentage of tortilla area counted as a burned spot.

ficantly higher mean values than the others. A comparison of the three sets of tortillas within each ID# showed no significant differences in toast spot area for ID#5 and ID#7. However, the toast spot area of set 1 was significantly greater than those sets for ID#1 and ID#2, the area of set 3 was significantly greater than that of set 1 for ID#3, the area of set 3 was significantly greater than those other of other sets for ID#4, and the area of set 3 was significantly greater than that of set 2 for ID#6.

Comparing the whiteness in the seven treatments of the three sets of tortillas showed that ID#4 was significantly less white than the others. A comparison of the three sets of tortillas within each ID# showed no significant differences in whiteness for ID#3, ID#6, and ID#7. However, the tortillas of set 1 were less white than those others for ID#1 and ID#2, those of set 1 were whiter than those of others for ID#4, and those of set 2 were whiter than those of others for ID#5.

A comparison of thickness in the seven treatments of three sets of tortillas showed that ID#4 and ID#7 were the thickest and ID#5 was least thick. Comparing the three sets of tortillas within each ID# showed no significant thickness differences for ID#3, between sets 2 and 3 for ID#1, between sets 1 and 3 for ID#2, between sets 1 and 2 for ID#6, and between sets 1 and 3 for ID#7. However, significant differences did occur among the three sets of tortillas for ID#4 and ID#5.

A comparison of weights in the seven treatments of the three sets of tortillas showed that ID#4 was significantly heavier than the others. Comparing the three sets of tortillas within each ID# showed no significant weight differences for ID#4, ID#5, and ID#6; between sets 2 and 3 for ID#1; between sets 1 and 3, and between sets 2 and 3 for ID#2; and between sets 1 and 2 for ID#3. However, significant differences did occur among the three sets of tortillas for ID#7.

Comparison of the diameters in the seven treatments of the three sets of tortillas showed that ID#4 and ID#5 had the largest diameters and ID#3 had the second largest. Comparing the three sets of tortillas within each ID# showed no significant differences for ID#1, ID#4, ID#5, and ID#7. However, the tortilla diameters of set 1 were larger than those for ID#2 and ID#3, and those of set 1 were larger than those of set 3 for ID#6.

Stretchability

The stretchability of the flour tortillas, expressed as maximum force and rupture distance required to break tortillas in the force-distance curve, is shown in Fig. 1. When the stretchability of tortillas was based on the resistance to rupture, the greater the maximum force was, the more stretchable the tortilla was. ID#5 needed the least maximum force. Conversely, when the stretchability of the tortillas was based on extensibility, the greater the distance to rupture the tortilla was, the more stretchable the tortilla was. ID#5 also needed the least distance to rupture (Fig. 1b). Tortilla ID#5 had the least stretchability, presumably because it was made by the die-cut method. ID#6 needed a higher maximum force but only a slightly greater rupture distance. Significant difference in stretchability occurred between regular and fat-free tortillas in only one of the two brands; tortillas made with the fat-free formulation were more stretchable. A comparison of the three sets with respect to the maximum force of the stretchability of the tortillas within each ID# showed no significant differences between sets 2 and 3 for ID#1; among the three sets for ID#2, ID#4, and ID#5; between sets 1 and 3 for ID#6; and between sets 2 and 1 for ID#7. Significant textural differences occurred among the sets of the tortillas, probably due to changes in formulation or changes in processing conditions.

TABLE II
Elastic Modulus of Commercial Tortillas

	Elastic Modulus (N/mm)		
ID#[a]	Strechability	Kramer Shear Cell	Firmness
1*	0.52–0.76	18.55–21.70	58.52–103.84
2	0.51–0.67	17.77–20.11	56.25–87.07
3	0.43–1.00	19.12–20.77	65.34–106.98
4	0.52–0.80	17.41–23.45	48.12–69.84
5	0.49–0.92	15.98–19.46	138.16–153.57
6*	0.69–1.11	20.90–28.75	83.10–120.78
7	0.38–0.88	16.94–19.24	52.46–81.42

[a] * Indicates fat-free tortillas.

Kramer Shear Cell Measurement

The ability of the tortilla to resist compression, shearing, and extrusion was expressed as the maximum force (N) and absorbed energy or work (Nmm) under the curve defined by the maximum force. Fig. 2 shows the maximum force results for the seven treatments of the three sets of tortillas. The tortillas in ID#5 needed smaller forces of compression, shearing, and extrusion to break and less energy to attain the failure point (maximum force). The tortillas made from a fat-free formulation (ID#6) needed greater force to break than those from the regular formulation (ID#7) because shortening, present in the regular formulation, contributes to the tender textural characteristics. A comparison of the three sets with respect to the maximum force of the Kramer shear cell of the tortillas within each ID# showed no significant differences between sets 1 and 3 for ID#1, among all three sets for ID#2, between sets 1 and 2 for ID#5, between sets 1 and 2 and between sets 2 and 3 for ID#6, and between sets 1 and 2 for ID#7.

Firmness

The firmness of the flour tortillas, expressed as compression force in the force-distance curve, is shown in Fig. 3. The greater the force required to compress the tortilla up to 30% deformation, the firmer the tortilla was. Comparison of the maximum forces to compress the flour tortillas up to 30% deformation showed that ID#5 tortilla was firmest (53.04 N) and ID#6 was ranked second firmest (46.99 N). The tortillas made from the fat-free formulation

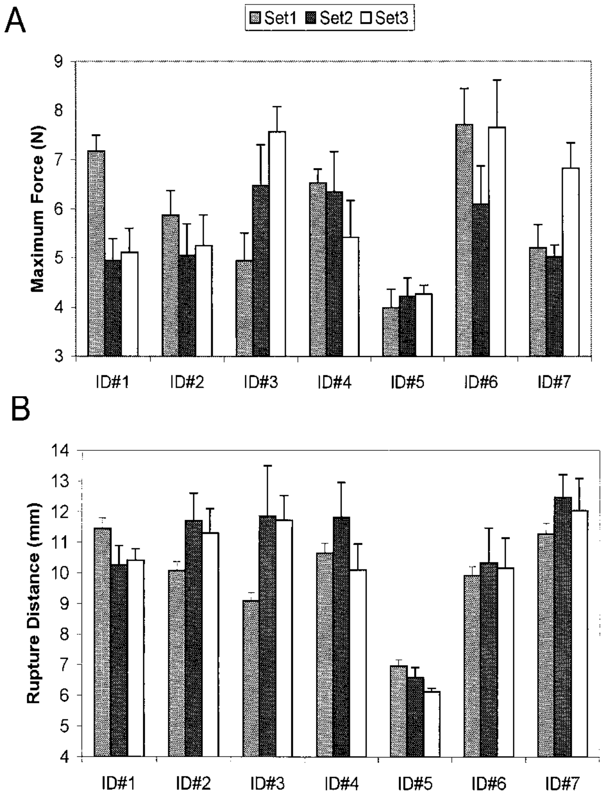

Fig. 1. Stretchability of commercial flour tortillas indicated by (**A**) maximum force and (**B**) rupture distance.

(ID#6) were firmer than those from the regular formulation (ID#7) because the shortening in the regular formulation contributes to the softer textural characteristic. The absorbed energy (work) required to compress tortillas up to 30% strain had almost the same trend as the maximum force, but ID#4 tortilla had the greatest work, although its force was not as high. That is because ID#4 was thicker, so it required more strain to work. Comparing the three sets with respect to the maximum force of the firmness of the tortillas within each ID# showed no significant differences between sets 2 and 3 for ID#1, between sets 1 and 3 for ID#2, between sets 2 and 3 for ID#4, between sets 1 and 2 for ID#5, between sets 1 and 3 for ID#6, and between sets 1 and 3 for ID#7. However, there were significant differences among all three sets for ID#3.

Elastic Modulus

Elastic modulus, expressed by the slope of the force (N) versus deformation at the straight-line portion, is shown in Table II. The ID#6 had a higher elastic modulus when the tortillas were stretched, sheared, and compressed. The tortillas made from the fat-free formulation (ID#6) had a significantly higher elastic modulus than those made from the regular formulation (ID#7) when stretched, sheared, and compressed. Comparing the three sets with respect to the elastic modulus of the stretchability of the tortillas within each ID# showed significant differences between sets 1 and 3 for ID#1 and ID#2; among the three sets for ID#3, ID#6, and ID#7; and between sets 1 and 2 and between sets 1 and 3 for ID#4 and ID#5. A comparison of the three sets with respect to the elastic modulus of the Kramer shear cell of the tortillas within each ID#, revealed no significant differences among the three sets for ID#1, ID#2, ID#3, and ID#7 and between sets 2 and 3 for ID#4, ID#5, and ID#6. Comparing the three sets with respect to the elastic modulus of the firmness of the tortillas within each ID# showed significant differences among the three sets for ID#1, between sets 1 and 2 and between sets 2 and 3 for ID#2 and ID#7, between sets 1 and 2 and between sets 1 and 3 for ID#3 and ID#5, between sets 1 and 3 and between sets 2 and 3 for ID#4, and between sets 1 and 3 for ID#6.

Rollability

The rollability of flour tortillas, as expressed by the peak force required to pull an axle that caused a tortilla to be rolled around a dowel, is shown in Fig. 4. The lower the peak force, the less work required to roll the tortilla, and the better the rollability. The ID#4 had a higher peak force because this type of tortilla was thicker than the others. However, no significant difference in peak force was found between tortillas made from regular and fat-free formulations. A comparison of the three sets with respect to the peak force of the rollability of the tortillas within each ID# showed no significant differences among the three sets for ID#1 and ID#6, between sets 1 and 2 and between sets 2 and 3 for ID#2, between sets 2 and 3 for ID#3, between sets 1 and 3 for ID#5, and between set 3 and between sets 2 and 3 for ID#7. However, significant differences did occur among the three sets for ID#4.

Variability of Textural Properties

The coefficient of variation (CV) value indicates variability for a given measurement. The higher the CV, the lower the repeatability of measurement and the less homogenous the tortillas. Table III shows that the rollability measurement had higher CV values (11.4%), which could indicate that the rollability measurement was less repeatable. Tortilla ID#6 displayed a higher CV value in maximum force in stretchability measurement; ID#2 displayed higher

TABLE III
Maximum Force (CV %) in Four Measurements for Texture of Commercial Flour Tortilla

ID#[a]	Set 1	Set 2	Set 3	Average
Stretchability				
1*	4.5	9.0	9.7	7.7
2	8.6	12.8	12.0	11.1
3	11.6	12.9	6.7	10.4
4	4.3	12.8	13.9	10.3
5	9.4	8.9	4.4	7.6
6*	9.5	12.9	12.7	11.7
7	9.2	4.9	7.5	7.2
Average	8.2	10.6	9.6	9.4
Kramer shear cell				
1*	5.7	11.9	8.1	8.6
2	3.8	10.7	12.2	8.9
3	3.2	6.2	7.3	5.6
4	4.0	11.1	8.1	7.7
5	1.2	2.7	11.7	5.2
6*	4.4	9.3	7.4	7.0
7	5.1	11.2	5.7	7.3
Average	3.9	9.0	8.6	7.2
Firmness				
1*	0.1	3.3	4.4	2.6
2	2.2	9.3	4.7	5.4
3	0.9	5.9	3.3	3.4
4	1.7	4.7	6.3	4.2
5	2.8	4.6	3.9	3.8
6*	1.4	4.3	4.0	3.2
7	6.9	5.3	10.2	7.5
Average	2.3	5.3	5.3	4.3
Rollability				
1*	8.1	11.6	13.6	11.1
2	6.2	13.8	5.3	8.4
3	7.6	12.2	17.5	12.4
4	7.3	14.1	16.7	12.7
5	6.4	9.5	14.3	10.1
6*	4.3	10.4	18.1	10.9
7	9.5	20.7	11.2	13.8
Average	7.1	13.2	13.8	11.4

[a] * Indicates fat-free tortillas.

CV values in Kramer shear cell measurement; and ID#7 displayed higher CV values in the measurements of firmness and rollability (Table III). ID#3 in sets 1 and 2 and ID#4 in set 3 displayed higher CV values in stretchability measurement; ID#1 in sets 1 and 2 and ID#2 in set 3 displayed higher CV values in Kramer shear cell measurement; ID#7 in sets 1 and 3 and ID#2 in set 2 displayed higher CV values in firmness measurement; ID#7 in sets 1 and 2 and ID#6 in set 3 displayed higher CV values in rollability measurement (Table III). These results indicate that the tortillas had heterogeneous textural properties within the sets studied.

SUMMARY

Objective textural measurements of commercial wheat flour tortilla were performed in three sets of seven types of tortillas. Two of those seven types were fat-free tortillas. The results indicate that there is a wide variability in the objective textural properties of tortillas among the same brand. Looking at the physical characteristics of tortillas (diameter, thickness, and weight), there was not a brand that had no significant differences among the three sets studied. Thickness was the characteristic that showed the largest variation; diameter showed the least of these three characteristics.

In terms of the appearance characteristics, identified by toast spots and whiteness, only ID#7 showed no significant differences among batches for these two characteristics. However, there were more significant differences within batches in terms of whiteness than with toast spots. Three brands did not show whiteness differences among batches, while only two did not show toast spots differences. Therefore, unless there is a minimum requirement for toast spots by the consumer or toast spots are used to evaluate processing conditions, the appearance of wheat flour tortillas can be related only by the whiteness.

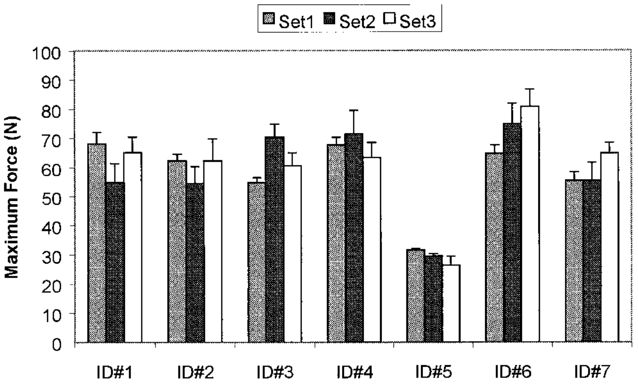

Fig. 2. Kramer shear cell maximum force required for rupturing commercial flour tortillas.

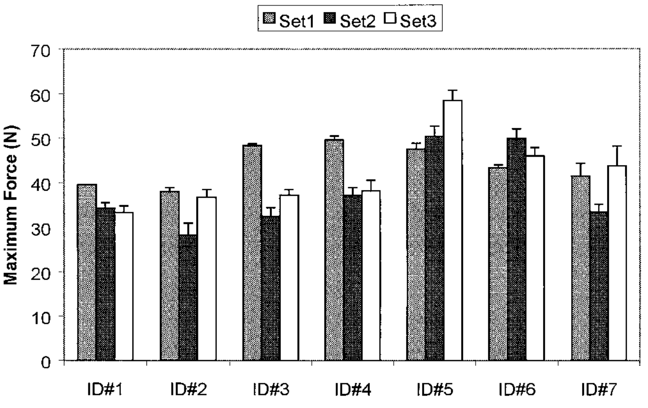

Fig. 3. Firmness of commercial flour tortillas tested using rounded-end-probe.

Only two brands among the seven did not show significant differences in moisture content among batches bought within 21 weeks. Moisture change during storage is a function of the formulation and packaging. Even though these factors were not evaluated in this study, the effect of moisture variability among sets of the same brand is reflected in the variation of the textural properties of the tortillas among sets within the same brand.

The objective textural properties were evaluated by the stretchability, Kramer shear cell measurements, firmness, and rollability maximum forces. The textural properties of tortillas showed significant differences in these properties within tortilla sets of the same brand. The two fat-free tortilla samples (ID#1 and ID#6) showed significant differences among the sets in all these textural properties, with the exception of rollability. The shortening in the formulation allowed show less variation in the rollability characteristic.

Although the tortilla brands studied over 21 weeks are all very well accepted by the consumers, the results of this study show that the textural properties of the wheat flour commercial tortillas varied significantly in the ranges obtained for characteristics of these baked products. However, during this study, variations in the formulation and fabrication methods could have affected the variability of the textural properties.

Even though the textural properties were objectively evaluated, the evaluation of a consumer product such as tortillas needs to be complemented with sensory evaluation, which was not in the scope of this study. Therefore, in selecting objective textural measurements for tortilla, this study indicates that the variability was the lowest for firmness (4.3%), followed by Kramer shear cell (9.4%), and stretchability (9.4%); the worst was for rollability (11.4%).

CONCLUSIONS

Significant differences in physical properties occurred among some commercial brands of flour tortillas and among the sets of some flour tortilla brands. Several textural properties of tortillas were measured by different techniques. Firmness, Kramer shear cell, and stretchability measurements were more repeatable than rollability measurements because of the lower CV. Tortillas made from a fat-free formulation were firmer than those made from a regular formulation for one of the two tortilla brands; they required more stretching and shearing force to break. Shortening gives tortillas textural properties that are softer and more tender. Significant textural differences occurred among the sets of the tortillas, probably because of changes in formulation or changes in processing conditions. Kramer shear cell and stretchability measurements are recommended because Kramer shear cell measures the force combined with compression, shearing, and extrusion. Stretchability measurements were repeatable and are an important textural property of wheat flour tortillas.

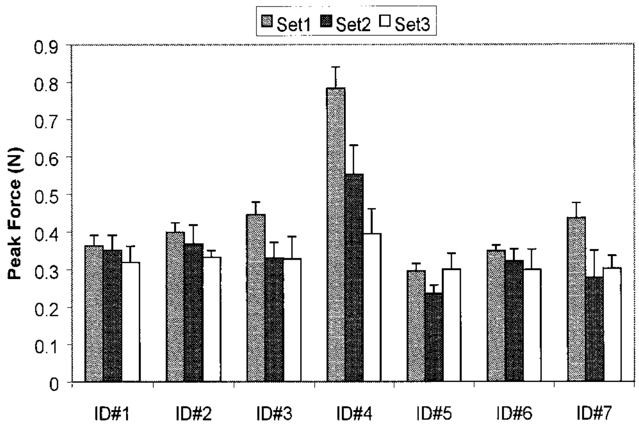

Fig. 4. Rollability of commercial flour tortillas indicated by peak force.

LITERATURE CITED

American Association of Cereal Chemists. 2000. Approved Methods of the AACC, 10th ed. Method 44-15A. The Association: St. Paul, MN.

Arámbula, V. G., Figueroa, J. D. C., Martinez-Bustos, F., Ordorica, F. C. A., and Gonzalez-Hernandez, J. 1998. Milling and processing parameters for corn tortillas from extruded instant dry masa flour. J. Food Sci. 63:338-341.

Baker, A. E., and Ponte, J. G. 1987a. Measurement of bread firmness with the universal testing machine. Cereal Foods World 32:491-493.

Baker, A. E., and Ponte, J. G. 1987b. Comparison of bread firmness measurements by four instruments. Cereal Foods World 32:486-488.

Baker, A. E., Walker, C. E., and Kemp, K. 1988. An optimum compression depth for measuring bread crumb firmness. Cereal Chem. 65:302-307.

Bedolia, S., de Palacios, M. G., Rooney, L. W., Diehl, K. C., and Khan, M. N. 1983. Cooking characteristics of sorghum and corn for tortilla preparation by several cooking methods. Cereal Chem. 60:263-268.

Bourne, M. C. 1982. Sensory methods of texture and viscosity measurement. Pages 247-279 in: Food Texture and Viscosity. M. C. Bourne, ed. Academic Press: New York.

Kim, Y. S., and Flores, R. A. 1999. Determination of bran contamination in wheat flours using content, color, and bran speck counts. Cereal Chem. 76:957-961.

Redlinger, P. A., Setser, C. S., and Dayton, A. D. 1985. Measurements of bread firmness using the Instron Universal Testing instrument: Difference resulting from test conditions. Cereal Chem. 62:223-225.

Suhendro, E. L., Almeida-Dominguez, H. D., Waniska, R. D., and Moreira, R. G. 1998a. Tortilla bending technique: An objective method for corn tortilla texture measurement. Cereal Chem. 75:854-858.

Suhendro, E. L., Almeida-Dominguez, H. D., Rooney, L. W., and Waniska, R. D. 1998b. Objective rollability method for corn tortilla texture measurement. Cereal Chem. 75:320-324.

Suhendro, E. L., Almeida-Dominguez, H. D., Rooney, L. W., Waniska, R. D., and Moreira, R. G. 1999. Use of extensibility to measure corn tortilla texture. Cereal Chem. 76:536-540.

Szczesniak, A. S., Brandt, M. A., and Friedman, H. H. 1963. Development of standard rating scales for mechanical parameters of texture and correlation between the objective and sensory methods of texture evaluation. J. Food Sci. 28:397-403.

Torres, P. I., Ramirez-Wong, B., Serna-Saldivar, S. O., and Rooney, L. W. 1993. Effect of sorghum flour addition on the characteristics of wheat flour tortillas. Cereal Chem. 70:8-13.

Twillman, T. J., and White, P. J. 1988. Influence of monoglycerides on the textural shelf life and dough rheology of corn tortillas. Cereal Chem. 65:253-257.

Walker, C. E., West, D. I., and Buck, J. S. 1987. Cake firmness measurement by the universal testing machine. Cereal Foods World 32:477-480.

Wang, L., and Flores R. A. 1999. Effect of different wheat classes and their flour milling streams on textural properties of flour tortillas. Cereal Chem. 76:496-502.

Yau, J. C., Waniska, R. D., and Rooney, L. W. 1994. Effect of food additives on storage stability of corn tortillas. Cereal Foods World 39:396-402.

[Received October 3, 2001. Accepted April 24, 2002.]