

Objective Rollability Method for Corn Tortilla Texture Measurement

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ABSTRACT

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An objective rollability method that imitates subjective rollability scores of corn tortilla texture was developed. Force and work required to pull an axle that caused a tortilla to roll around a dowel were measured. The sensitivity of the technique to detect changes in corn tortilla texture during storage was evaluated, and other factors affecting objective rollability and tortilla texture were studied. The objective rollability technique was fast, simple, and sensitive to changes in the tortillas, and worked effectively on commercial samples. Data was significantly correlated to subjective rollability and flexibility scores. Textural differences among

fresh tortillas during the first 24 hr of storage, and among tortillas with different thicknesses and additives, were detected by the objective rollability method. Thicker tortillas required more force and work to roll than thin tortillas. The objective technique is more sensitive to changes in texture than subjective evaluations, which do not detect differences in tortilla variability during the first 24 hr after baking, and it can be used to evaluate the effect of formulation and processing changes on fresh and stored tortillas.

The tortilla industry is one of the fastest growing sectors of the U.S. baking industry. Retail sales for corn tortillas and tortilla chips in 1996 were over 4 billion U.S. dollars (Barret 1996). Retail sales of table tortillas alone were nearly 1 billion dollars.

Shelf-stability (staling), the ability of the product to retain its original texture and sensory characteristics, is a significant problem in corn tortillas. Staling is generally associated with increased crumb firmness and deterioration of the texture of baked products during storage (Hebeda et al 1991). Aged tortillas are firmer, more rigid, and less rollable than fresh tortillas. Fresh tortillas are soft and roll easily without cracking, whereas aged tortillas are rigid, brittle, and crack when they are rolled.

Tortillas are rolled, torn apart, bent, or folded, and the texture is evaluated subjectively. Subjective rollability methods are most commonly used to monitor changes in corn and wheat tortilla texture during storage or in response to the addition of additives (Waniska 1976, Bello et al 1991, Friend et al 1993, Suhendro et al 1993, Yau et al 1994).

During the subjective rollability test, a tortilla is rolled around a dowel and the extent of cracking is evaluated by human judges. The subjective method is simple and reflects the way tortillas are handled before consumption. However, there can be significant variability in the rollability scores from person to person, and the method is not sensitive to changes in fresh tortilla texture (Yau et al 1994, Suhendro 1997).

Objective texture measurements that can imitate subjective measurements and that are sensitive, reliable, and appropriate to monitor the changes in flexibility and rollability of tortillas during storage and as a result of reformulating are needed. Therefore, the purpose of this study was to develop and evaluate an objective rollability method using a texture analyzer to imitate subjective rollability as performed by human judges.

MATERIALS AND METHODS

Materials

Corn tortillas were produced in the Texas A&M Tortilla Processing Pilot Plant. Fifteen samples of commercial corn tortillas from 12 brands were collected from selected Texas markets. Three out of the 12 brands were collected from two separate bags of the same products, purchased at the same time.

Pilot Plant Tortilla Preparation

Corn tortillas were produced using nixtamalized corn flour (NCF, Tortilla #4, Valley Grain Products, Muleshoe, TX) in the Texas A&M Pilot Plant. Preservatives (0.36% baker's percentage) fumaric acid (Denka Chem. Co., Houston, TX) and potassium sorbate (Sorbitat-K, Pfizer, New York, NY) were dissolved in heated, distilled water. The NCF was hydrated with the water-preservative solution using a baker's percentage of 115% water (based on NFC) and mixed with a hook attachment for 1.5 min at slow speed to produce masa with $58 \pm 1\%$ moisture and pH of 5.4 ± 0.2 .

The masa was placed into a low-density polyethylene bag and rested at room temperature for 10 min. To evaluate the effect of storage time on subjective and objective rollability values, the masa was sheeted (model CH4-STM, Superior Food Machinery, Pico Rivera, CA) to make unbaked tortilla disks (26 ± 1 g). The disks were baked in a three-tier, gas-fired oven (model 3106 INF, Food Machinery Inc., Pico Rivera, CA) at a temperature of 550–600°F for 45 sec. To evaluate the effect of thickness on tortilla texture, the masa was sheeted to make unbaked tortilla disks of different thicknesses (26 ± 1 g and 33 ± 1 g) which were baked in a three-tier (top 350°C, medium 295°C, bottom 350°C) gas-fired oven (model C-0440, Superior Food Machinery Inc., Pico Rivera, CA) for 50 sec. Stacks of 20 tortillas were stored inside low-density polyethylene bags at 25°C for up to 240 hr.

Subjective Tortilla Texture Measurements

In the rollability technique, tortilla was wrapped and rolled around a 1-cm wood dowel. Rollability was subjectively recorded by a trained evaluator using a scale of 1–5 (1 = unrollable [worst], 5 = no cracking [best]).

In the flexibility technique, tortillas were subjectively evaluated for overall flexibility (i.e. firmness, squeezability, and breakability) by a trained evaluator. The overall firmness score was rated 1–5 (1 = firm, and rigid [worst], 5 = soft and flexible [best]).

Objective Rollability Measurement

The objective rollability measurement was conducted using a TA.XT2 Texture Analyzer (StableMicro Systems, Haslemere, UK/Texture Technologies Corp., Scarsdale, NY).

The objective rollability technique utilized a custom-designed rollability fixture. The fixture consists of an acrylic cylindrical dowel (1.9 cm dia.) and a metal chain that connects the cylinder dowel to the texture analyzer arm (Fig. 1). Before conducting the rollability test, the probe was calibrated to a distance of 160 mm from the analyzer arm to the platform with a metal wire that held the tortilla on the top of the dowel. A tortilla was fixed onto the dowel such that the tortilla's edge was firmly clasped by the metal wire (Figs. 1 and 2). The tortilla was positioned with the double-baked tortilla side down. The force required to pull an axle that turned

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the dowel, making the tortilla roll up, was then recorded. The test was conducted using “force in tension mode” and the “return to start” option with pre- and postspeed set at 10.0 mm/sec. The trigger force was 0.05 N. The probe traveled a 50.0-mm distance at 3.0 mm/sec during testing (Table I).

Statistical Analysis

Coefficient of variation (CV) was evaluated for each treatment. The effect of storage time on texture was evaluated using one way analysis of variance (ANOVA) in a completely randomized experimental design. Treatment means were taken on five to six readings from five to six individual tortillas, and were compared using protected Fisher’s least significant differences (LSD) at $\alpha = 0.05$. SAS statistical software package (ver 6.04) was used for the statistical analyses (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

Subjective Texture Measurement

As storage time increased, tortillas became firmer and less flexible. Subjective flexibility analysis showed that there were significant decreases in flexibility in the tortillas during the first 24 hr of storage (Fig. 3). However, the subjective rollability technique was not sensitive enough to detect differences in tortilla

texture. Yau et al (1994) and Fernandez-de-Castro (1988) also found the rollability method was insensitive during the initial 24 hr of tortilla storage.

The subjective rollability method evaluates the cracks and breaks that occur during rolling but does not evaluate the increase in tortilla rigidity that occurs during storage. Thus, the subjective method was not sensitive enough to measure textural changes in tortillas during the first 24 hr of storage. For this reason, the subjective firmness or flexibility test was designed to evaluate the overall tortilla flexibility, including softness, firmness, pliability, and squeezability. The overall subjective firmness test was more sensitive than subjective rollability during the initial 24 hr of storage. However, it is difficult to quantify the subjective firmness-flexibility test because it measures the overall parameters of tortilla flexibility.

Objective Rollability Measurement

Typical rollability curves using the 1.9-cm dia. dowel are shown in Fig. 4. Total work required to drag and roll the tortilla around the dowel was calculated as the area under the rollability curve. Force required to roll a tortilla on the dowel one revolution was called the first peak of the curve.

All of the commercial corn tortillas used in this study were unpuffed; however, they varied in diameter, weight, thickness,

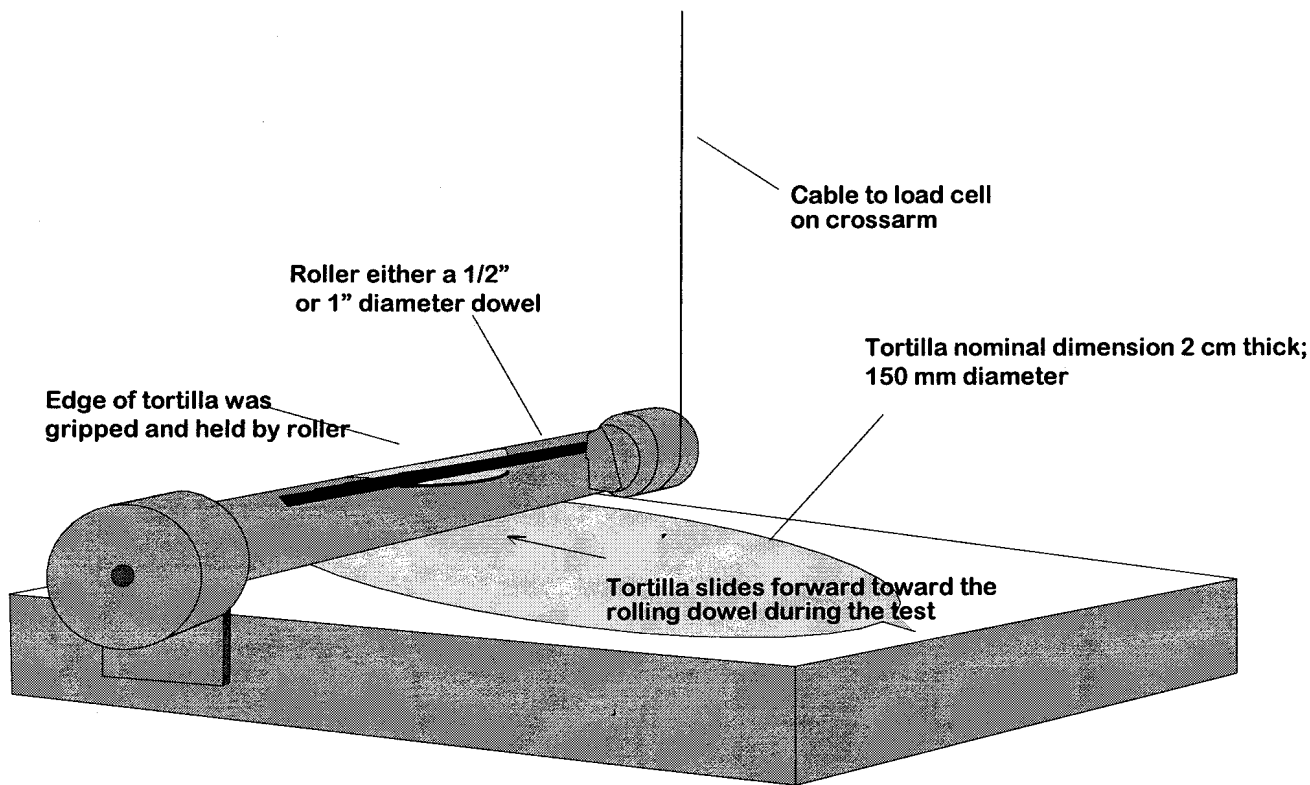


Fig. 1. Scheme of apparatus to objectively measure the rollability of corn tortillas.

TABLE I
Rollability Test Settings for the TA.XT2 Texture Analyzer

Method Graph Type	Parameter Force vs. Distance	Setup Option	Parameter Return to Start
Auto-scaling	On	Force units	Newtons
Force threshold	0.5	Distance format	mm
Peak confirmation	Off	Pretest speed	10 mm/sec
File type	Lotus 123	Test speed	3 mm/sec
Display and export	Plotted points	Posttest speed	10 mm/sec
Acquisition rate	50 pps	Force	Newtons
Result file	Closed	Distance	50 mm
Force unit	...	Trigger type	Auto
Contact area	...	Trigger force	0.05 Newtons

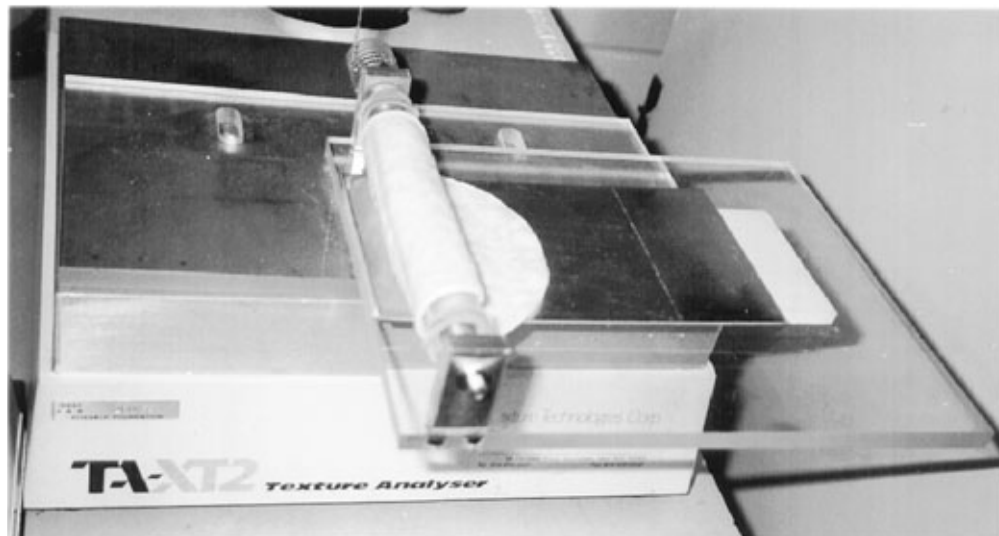
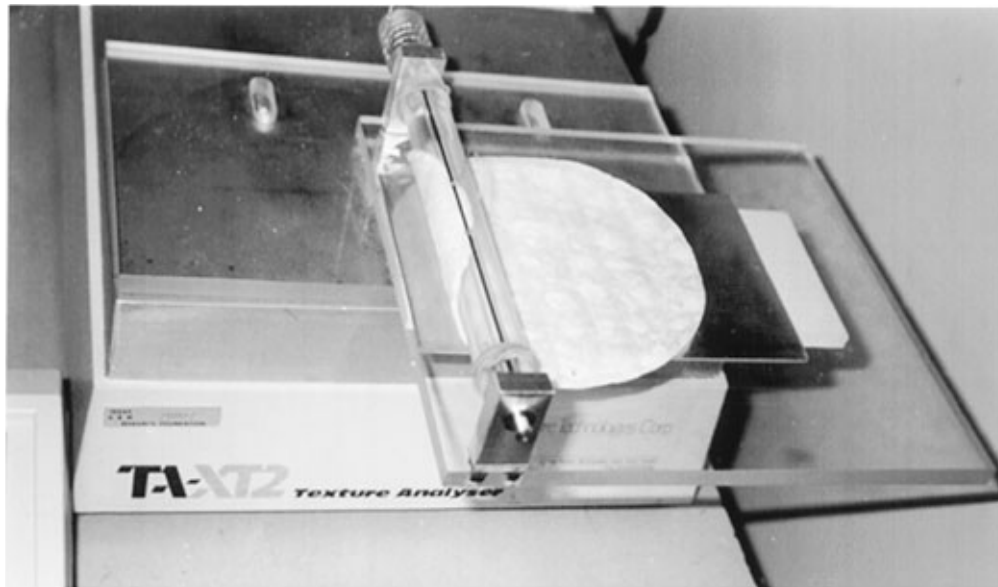


Fig. 2. Tortilla being fixed and rolled around the dowel.

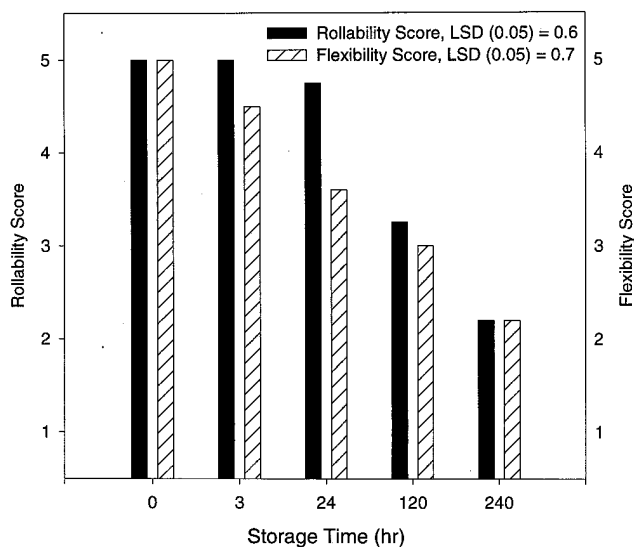


Fig. 3. Subjective rollability and flexibility scores of corn tortillas stored for 10 days at room temperature.

moisture, and pH (Table II). These variabilities were presumably due to processing conditions, formulations, and storage time.

The objective rollability test was extremely sensitive to changes in texture among the commercial tortillas. Average CV of the commercial tortillas within the same brand in the same bag was 8.1 and 9.0% for force and work required to roll, respectively (Table II). This low CV suggested that the objective rollability technique was a repeatable and a sensitive textural technique, and this also suggested that, within the same bag (or workshift), the commercial tortillas were quite homogenous, however, the tortillas differed between bags (workshift) and commercial brands (Table II).

The CV values for objective rollability scores for the set of uncontrolled laboratory tortilla samples were 23.7% for peak force and 23.2% for work to roll. These high CV values indicated that the objective rollability technique was extremely sensitive to the normal variability present under pilot plant conditions. This variation in corn tortillas could arise during sheeting and baking that would yield abnormal, under- or overbaked tortillas. The subjective rollability method, on the other hand, was not as sensitive to the sample's variability. The laboratory tortillas were more heterogenous than commercial tortillas sampled from the same bag and the same brand, and the objective rollability technique was sensitive enough to detect differences among all sample sets.

TABLE II
Physical and Textural Properties of Commercial Tortillas from Selected Texas Markets

Sample ID ^a	Diameter (cm) ^b	Weight (g) ^b	Thickness (cm) ^b	Moisture (%) ^c	pH ^c	Subjective Evaluation		Objective Rollability	
						Rollability ^b	Flexibility ^b	Force (N) ^b	Work (Nm × 10 ⁻³) ^b
1	14.0	15.9	1.24	38.2	10.6	4.7	3.6	0.20	9.1
2a	13.5	20.3	1.56	48.3	5.2	5.0	2.2	0.34	7.7
3	13.4	19.2	1.64	45.8	5.0	4.3	2.5	0.27	10.8
4a	13.5	18.6	1.67	44.5	5.5	4.4	2.3	0.22	8.2
5	14.4	24.3	1.76	48.6	5.6	3.6	2.5	0.28	11.8
6	13.9	21.8	1.78	43.1	10.9	2.4	3.9	0.32	12.7
7	13.5	24.9	1.79	46.6	9.5	3.7	2.5	0.31	13.0
8	14.4	27.4	1.87	44.6	5.5	4.4	2.5	0.38	18.5
9b	14.4	27.4	1.87	47.5	5.0	2.3	2.1	0.65	37.9
10b	13.3	25.5	1.89	48.6	4.9	3.8	4.5	0.33	14.5
11	14.6	29.5	1.92	46.8	4.6	1.6	1.9	0.90	37.2
12c	14.5	30.0	1.97	46.5	4.7	1.1	1.5	1.10	52.3
13	13.9	24.9	1.98	45.7	5.5	3.5	1.4	0.40	18.8
14c	14.5	29.4	2.04	45.3	5.0	2.0	1.1	0.81	41.4
15	13.7	28.7	2.15	47.4	5.6	1.9	1.7	0.52	23.8
CV ^d (%)	3.4	18.0	12.2	3.1	1.8	7.9	4.5	8.10	9.0
LSD ^e	0.5	0.9	0.08	1.4	0.1	0.3	0.4	0.07	3.7

^a Tortilla samples followed by the same letter were from different bags of the same brand purchased on the same day.

^b Values are means of five observations.

^c Values are means of two observations.

^d Coefficient of variation.

^e Protected Fisher's least significant difference ($P \leq 0.05$) using one-way analysis of variance.

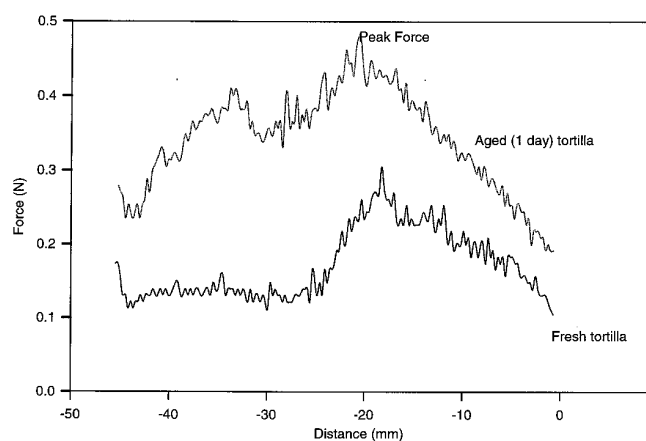


Fig. 4. Typical objective rollability curves for fresh and aged corn tortillas.

The effect of storage time on corn tortilla texture was evaluated on laboratory corn tortilla samples. Work and force to roll tortillas increased as storage time increased, especially during the first 24 hr of storage (Fig. 5). While subjective rollability tests were not sensitive to texture differences that occurred within the first 24 hr (Fig. 3), the objective rollability test was extremely sensitive and was able to differentiate fresh tortillas from one day old tortillas.

To determine the effects that tortilla thickness had on the variability of the method, the extent of puffing and the thickness of the laboratory samples were controlled so that the samples evaluated were more homogenous. The effect of thickness was evaluated also on commercial corn tortilla samples.

Force and work required to roll thick tortillas were greater than that required to roll thin tortillas (Table III). Tortilla thickness did not affect the objective rollability values of fresh laboratory tortillas (0 days of storage) but significantly affected the rollability of tortillas that had been stored for ≤ 24 hr. The effect of thickness on tortilla texture was more significant as storage time increased. Subjective rollability scores supported these results.

The effect of thickness in the commercial corn tortillas was similar to that in the laboratory tortillas. Thicker tortillas were

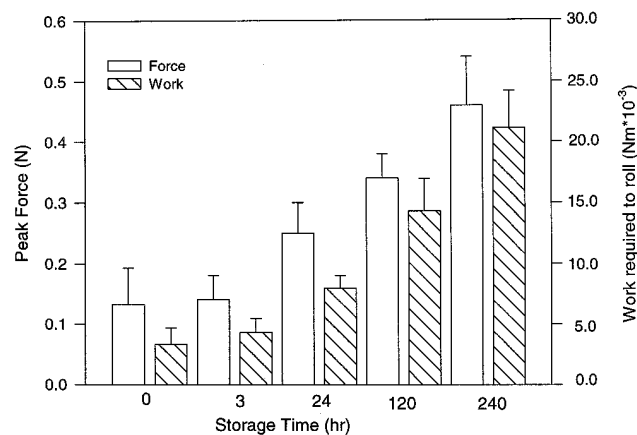


Fig. 5. Force and work required to roll laboratory-prepared corn tortillas during storage.

TABLE III
Effect of Thickness on Texture of Laboratory Corn Tortillas

Treatment ^a	Storage (days)	Objective Rollability		Subjective Rollability
		Force (N)	Work (Nm × 10 ⁻³)	
Thin	0	0.17	4.84	5.0
	1	0.26	9.59	4.7
	3	0.39	18.88	4.0
Thick	0	0.15	5.40	5.0
	1	0.35	15.65	4.0
	3	0.59	30.46	2.6
LSD ^b		0.04	3.20	0.4

^a Observations per treatment ($n = 5$).

^b Protected Fisher's least significant difference ($P \leq 0.05$) using one-way analysis of variance.

firmer, less flexible and required more force and work required to roll than thinner tortillas (Table II).

Pearson Correlation Among Objective Rollability and Subjective Texture Techniques

Pearson correlation analysis was conducted on both pilot plant and commercial sample data. Objective measurements of force

TABLE IV
Pearson Correlation Coefficients Among Subjective and Objective Textural Properties of Commercial Table Tortillas from Selected Texas Markets^a

Properties	Diameter	Weight	Thickness	Moisture	Subjective		Objective Rollability Force
					Rollability	Flexibility	
Weight	0.56						
Thickness	ns ^b	0.83					
Moisture	ns	0.55	0.67				
Subjective rollability	-0.58	-0.78	-0.64	ns			
Subjective flexibility	-0.57	-0.55	-0.42	ns	0.82		
Rollability force	0.67	0.78	0.53	ns	-0.82	-0.69	
Rollability work	0.69	0.78	0.53	ns	-0.82	-0.70	0.98

^a Correlations ($n = 15$) are significant at $P \leq 0.05$.

^b Not significant.

and work required to roll were significantly correlated to both subjective evaluations (Table IV).

The Pearson correlation coefficients among the objective force and work required to roll was also significantly correlated to subjective rollability on laboratory samples ($r = -0.89$ and -0.92 for force and work required to roll, respectively). Work required to roll tortillas had the highest correlation coefficients and could be utilized to predict rollability and flexibility of corn tortillas. Thus, the rollability technique effectively measured textural properties of corn tortillas during storage.

CONCLUSIONS

The objective technique measured the force and work required to roll a tortilla. The technique detected changes in corn tortilla textural properties during storage and was significantly correlated with subjective rollability and flexibility scores.

The objective rollability technique is a useful technique to detect the homogeneity among the samples tested. High CV values indicate that the samples were heterogenous and low CV values indicate samples tested were more homogenous.

The rollability technique has good potential to objectively quantify and monitor textural changes in corn tortillas. The objective technique was sensitive enough to detect texture differences among fresh tortillas. Therefore, the technique supplemented information gained in the subjective rollability test. The technique is subject to modification, as needed, for various applications and is recommended for corn tortilla quality control and product development purposes in commercial settings. The physical properties of corn tortillas and the functionality of food additives for improvement of the shelf-stability of corn tortillas could be evaluated with the objective technique.

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