

# Validation of Measurement of Textural Properties of Cooked Noodles by Extension-Based Cutting

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## ABSTRACT

A new method using an extension-based cutting test was developed to measure textural properties of cooked noodles. Noodle ring samples were prepared by connecting both ends of a noodle strip before cooking. The test geometry consisted of a 5-mm diameter rig acting as a moving head with a blade attached at the bottom. Seven noodle textural parameters were measured on noodles with different starch contents (0, 5, 10, 15, 20%): cutting force; toughness and failure strain (measured by extension tensile test); cutting force and work-to-cut (measured by compression test); and firmness and chewiness (measured by sensory evaluation). ANOVA evaluation based on added starch contents indicated that tensile cutting force and toughness yielded the highest *F* values. Principal component analysis showed that tensile cutting force and toughness were the most critical contributors to PCI eigen values among the seven parameters. In canonical correlation analysis, the canonical variate (CV) for textural parameters of the tensile test exhibited a larger correlation with sensory evaluation than CV for the standard compression cutting test. The new extension cutting test offers improved data reproducibility and accuracy compared with the traditional cutting test performed through compression.

Physical properties of noodles generally are determined in terms of texture, i.e., mechanical, geometric, and surface attributes. These properties are very difficult to measure due to the intrinsic irregularity of noodle size and shape that results from varying roll gaps in processing and compression or extension during storage (13,15). Cutting force is one mechanical attribute that is a known factor in determining noodle quality. According to the existing method, cutting force is defined as a peak force in compression (10). However, due to limited noodle thickness, this test offers poor reproducibility.

The mechanical properties of noodles have been examined by several researchers. TPA (texture profile analysis) (1,4), cutting force and work-to-cut (10), firmness (11), and stickiness (7) are parameters that have been correlated with sensory properties. However, the small size of noodle test samples, combined with their irregular shape, may cause significant deviations among the test results when compressed on a platform with a cylinder probe or knife.

Instrumental methods typically are based on compression, extension, bending, and torsion. The tensile test is one of the oldest and most widely used methods to measure material properties of foods such as doughs (12) and *chapatti* (3). It has not been widely applied to texture measurements of cooked noodles because the tensile test is one of the hardest to perform properly and it is the least appropriate for a highly deformable material such as a noodle dough. Lii and Chang (8), Kasemesuwan and coworkers (6), and Guan (2) adopted a two-grip test geometry for a single noodle strip. This test geometry, however, resulted in poor data reproducibility because the act of gripping the noodle sample led to breakage and distortion within the gripped sample portion. Several solutions have been developed for other materials, including preparation of dumbbell-shaped samples, locking clamps, and self-tightening grips (16). Therefore, if a better modification were developed to alleviate these effects in the measurement of noodle texture, the tensile test could be successfully applied.

In this study, a new test geometry was used to avoid the act of clamping or gripping the noodle strip during the tensile test. Noodle samples were prepared as a ring shape. In the apparatus described, one rig used in the extension tensile test was replaced with a blade, and the ring of cooked noodle was stretched, recording the tensile strength. The method was statistically vali-

dated in terms of data reproducibility and accuracy.

## MATERIALS AND METHODS

The wheat flour used in this study was a commercial product (Daesun Flour Mills Co., Korea) containing 65% hard red spring and 35% soft white wheat harvested in 2004 in the United States. Potato starch (Joon-gang Chemical Co., Korea) was added at 5, 10, 15, and 20%, respectively, on a 500-g flour basis. A 2% NaCl (purified grade I, Doyumwom Co., Korea) solution and distilled water were added to the mixed flour and starch composite.

### Preparation of Noodles

A pilot-scale laboratory noodle machine (Seoju Engineering Co., Korea) was used for the preparation of the noodle samples. Noodles were made in the laboratory using 500 g of mixed flour, 200 g of distilled water, and 4 g of salt. Ingredients were combined in a mixer, and the salt solution was added to the flour for 30 sec at low-speed mixing. Mixing continued for 4.5 min at low speed, followed by 8 min at high speed, and an additional 2 min at low speed. The dough was then allowed to rest in a plastic bag at room temperature for 15 min to distribute water uniformly throughout the flour particles. The dough was passed unidirectionally through two rollers in six successive steps with decreasing roll gaps of 4.0, 3.7, 2.9, 2.0, 1.6, and 1.3 mm. The final sheeted noodle dough was cut into strips 1.3 mm thick, 6 mm wide, and 17 cm long.

### Preparation of Ring-Type Samples

For the tensile test, a raw noodle ring was formed by connecting the noodle strip ends together. One end was "glued" onto the other end with a little water and pressing with fingers. The ring circumference, width, and thickness were 15.5 cm, 6 mm, and 1.3 mm, respectively. Five ring samples were boiled in a container with 500 mL of distilled water for 7 min and cooled in tap water for 30 sec. Cooked samples were drained on a plastic screen with apertures of 0.5 mm for 10 sec. Each starch and flour sample series was analyzed in duplicate.

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### Instrument Test

Measurements were performed with a texture analyzer (TA-XT2, Stable Micro Systems, United Kingdom) at a crosshead speed of 6 mm/sec in extension and compression modes. The extension test geometry consisted of a cylindrical rig (5-mm diameter) attached to the crosshead and a single blade (6° angle) gripped by a bottom grip (Fig. 1). The ring of cooked noodle was stretched in between. The rig and blade were cleaned and lubricated with vegetable oil after each test to remove any end effect caused by friction between the surface and the test sample. The cutting measurements of the noodles were replicated 10 times for each of the five levels of starch content. To determine the maximum test limit of extension applied in the cutting test (Fig. 2), the single blade was replaced with a round rig. In the compression mode testing protocol, a noodle strip resting on the platform was cut by the same single 6°-angled blade.

The textural parameters captured by the tensile test were cutting force, toughness, and failure strain; the compression test measured cutting force and work-to-cut (10). Cutting force is defined as the peak force on the force-deformation curve; toughness is the area under the curve. Failure strain is defined as the ratio of change in length to

the original length at the cutting force; work-to-cut is the area under the curve.

### Sensory Evaluation

Ten trained panelists (graduate students at Dongguk University, Seoul, Korea) participated in the sensory evaluation of firmness and chewiness of the cooked noodles. Noodles were prepared in the same manner as in the instrument tests and evaluated using the method described by Oh and co-workers (10). Firmness was defined as the force required to masticate through a noodle

strand between the molar teeth. Firmness was evaluated on a scale of 1 to 10, with the highest firmness being 10. Chewiness was the length of time required to chew 10 g of cooked noodle at the rate of one bite per second to a consistency small enough to swallow.

### Statistical Analysis

Analysis of variance (ANOVA) for the single factor, added starch content, and principal component analysis (PCA) were performed for seven textural parameters of

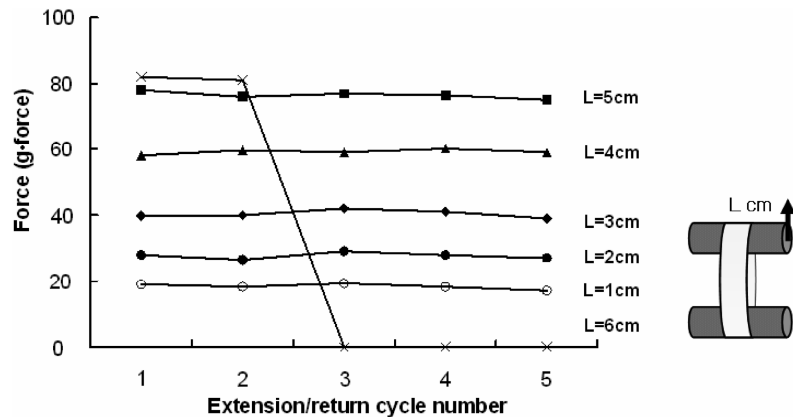


Fig. 2. Change in peak forces repeatedly measured at a fixed extension (six levels) according to extension/return cycles.

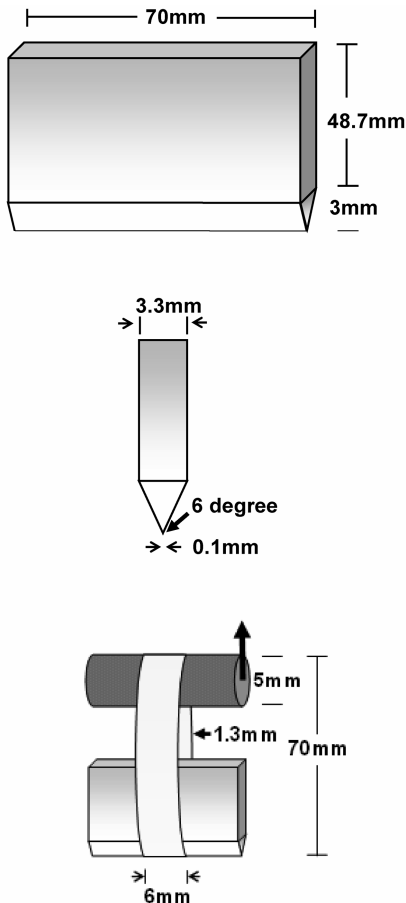


Fig. 1. Schematic representation of device used to cut cooked noodle ring samples by extension.

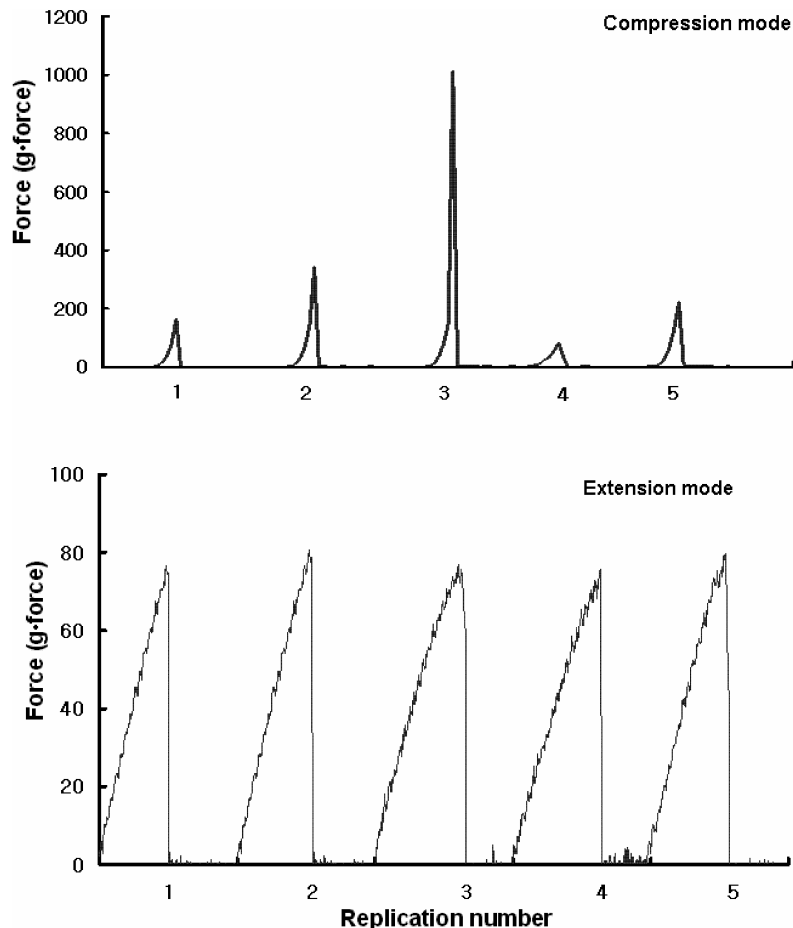


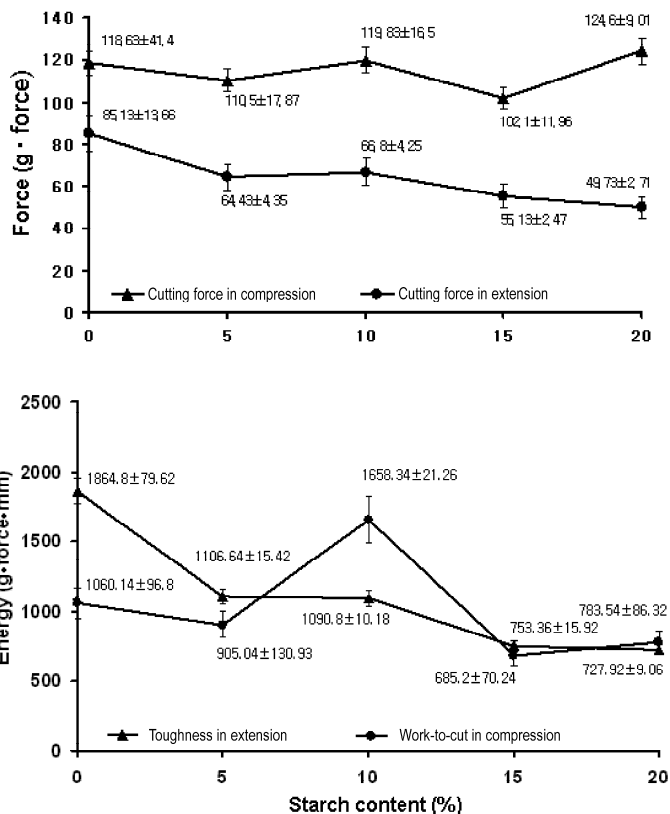
Fig. 3. Comparison between tensile cutting curves and compression cutting curves in five replications, using the ring control (no starch) cooked noodle.

instrument and sensory tests. In canonical correlation analysis, one of two groups (three tensile test parameters and two compression test parameters) and one group (two sensory evaluation parameters) were assigned to two canonical variates (CV) that were correlated with each other. The data were analyzed using SAS software (SAS Institute, Cary, NC).

## RESULTS AND DISCUSSION

### Determination of Valid Extension Test Range

If a ring sample is excessively extended, weakest part of the sample, the glued end, may rupture. Care must be taken to ensure that the sample is cut on the edge of the blade before the glued region begins to separate. Five extension and return cycle tests were performed to determine the limit of extension possible for the cutting test, as determined by a force decrease during the extension cycles. A pair of rigs without a blade were used to stretch the ring control (no starch) noodle (Fig. 2). Peak force repeatedly measured at a fixed extension remained constant in the set range of 1–5 cm. However, peak force at a 6-cm extension abruptly decayed after the second cycle, indicating that it may cause damage on the weakest part on the ring. The optimum test condition was determined to be a 5-cm extension,



**Fig. 4.** Comparison between cutting forces (means and standard deviations) of tensile and compression tests and between toughness and work-to-cut, using cooked noodles with different starch contents.

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because it provided sufficient extension to allow the sample to be cut with a blade.

### Data Reproducibility

Typical curve data from the compression and tensile tests are shown in Fig. 3. Curves from the tensile test were uniform in terms of shape, peak, area, etc., compared with those of the compression test. In line with these results, standard deviations of cutting force replicates using the tensile test were smaller than those of the cutting force replicates using the compression test (Fig. 4), suggesting that the tensile extension cutting test leads to better data reproducibility than the corresponding compression test.

Data reproducibility can be related to data discrimination because a higher de-

gree of reproducibility reduces data variability and results in better discrimination between mean values of samples. Data discrimination was evaluated by ANOVA and PCA. In single-factor ANOVA, *F* values were estimated to determine whether the mean values of individual textural parameters of instrument tests were significantly different between noodles with different starch contents (Table I). The textural parameters of the tensile test generally had larger *F* values than those of the compression test, indicating that the extension test offered an improved ability to differentiate the noodles. Cutting force measured by the tensile test displayed the highest *F* value.

In PCA, principle components (PC) were calculated with seven parameters: five from instrument tests and two from sensory eval-

uation. The contributions of PC1 and PC2 were 48.3 and 19.3%, respectively; the contribution of the other PCs was relatively negligible. PC1 was better than PC2 for differentiating the samples (Fig. 5). The tensile test cutting force and toughness parameters yielded higher eigen values for PC1 than for the other parameters (Table II), implying that these two parameters best described the differences between the noodles and confirming that cutting by extension is a valuable instrument method.

### Data Accuracy

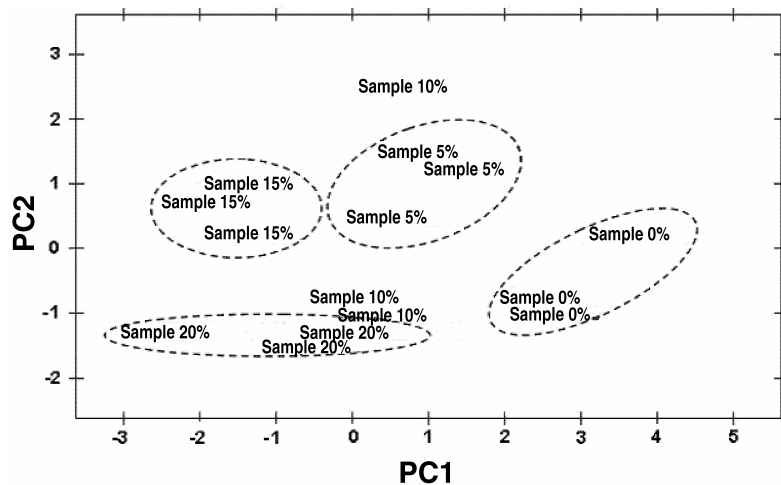
While instrument data should show good reproducibility, they should also have a high correlation with sensory values. This concept was assessed using starch additions to study the relationship between instrument textural parameters and sensory tests.

Cutting force and toughness values for the tensile test decreased with increasing starch content, whereas those for the compression test, in which work-to-cut corresponds to toughness, did not show this tendency (Fig. 4). Oh and coworkers (10) reported that noodle toughness declined with increasing starch addition, which is consistent with data from the tensile test but not with those from the compression test. In addition, cutting force and toughness values derived from the tensile test had better correlations with firmness and chewiness, as determined by sensory evaluation (Table III), which is consistent with the literature (5). This suggests that the tensile test data for noodle properties are better indicators of sensory properties than the compression test data.

Canonical correlation analysis (CCA) and PCA both reduce the number of original variables to several CVs and PCs, respectively. The PCs are automatically calculated by linear equations with all the original variables, whereas CVs are calculated by linear equations with intentionally separated groups of original variables (9, 14). In this study, the original variables were divided into three groups (extension, compression, and sensory parameters) that corresponded to CV extension, CV compression, and CV sensory, respectively. The correlation coefficients between the parameters in each group and the relevant CVs were large enough to allow further canonical analysis (Table IV). Only the first canonical correlation was significant. The first canonical coefficients are listed in Table V. The magnitudes indicate the weights or loadings to represent their contributions to the related CV. Cutting force was a prime factor for CV extension, and work-to-cut was a prime factor for CV compression. Calculated CVs are plotted in Fig. 6, highlighting the fact that CV extension offers a higher correlation with CV sensory than with CV compression, suggesting that the tensile test is a better predictor of sensory parameters of noodles than is the compression test.

**Table I. Significant difference in means of textural parameters of instrument tests for noodle samples with different starch contents**

Statistical Parameter	Compression Test		Tensile Test		
	Cutting Force	Work-to-Cut	Cutting Force	Toughness	Failure Strain
<i>F</i> value	0.47	1.56	11.66	10.86	3.84
<i>Pr &gt; F</i>	0.7587	0.258	0.0009	0.0012	0.0383



**Fig. 5. Principal component analysis of textural parameters of cooked noodles with different starch contents (sample 0–20%) in instrument and sensory tests, showing coordinate values (PC1:PC2) of samples in the first two principal components' space.**

**Table II. Eigen values of individual textural parameters for principal components PC1 and PC2**

Principal Components	Compression Test		Tensile Test			Sensory Evaluation	
	Cutting Force	Work-to-Cut	Cutting Force	Toughness	Failure Strain	Firmness	Chewiness
PC1	-0.2504	-0.615	0.50727	0.514765	0.2835	0.4488	0.359784
PC2	0.64893	-0.6177	0.06999	0.170055	0.3296	-0.23191	0.03356

**Table III. Correlation coefficients for textural parameters of instrument and sensory tests**

Sensory Test	Compression Test		Tensile Test		
	Cutting Force	Work-to-Cut	Cutting Force	Toughness	Failure Strain
Firmness	-0.5975	-0.0156	0.6816	0.7046	0.3737
Chewiness	-0.614	0.1857	0.6613	0.5802	0.2808

## CONCLUSIONS

Instrument measurement of cutting force using the compression blade method has been difficult to perform due to technical problems associated with loading a small sample with an irregular shape. To overcome these difficulties, a tensile cutting test using a noodle ring sample was devel-

oped. Data quality using this method was validated in terms of reproducibility and accuracy. The new method was valid in measuring noodle texture and offered improvement over the existing compression cutting method. Preliminary testing to determine the maximum extension limit ensured that cutting occurred before any weak portion of the ring sample began to sepa-

rate. We concluded that the new method of cutting a noodle ring sample by extension was suitable for use in noodle texture measurements.

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Table IV. Correlation coefficients between textural parameters and relevant canonical variates

Canonical Variate	Compression Test		Tensile Test			Sensory Evaluation	
	Cutting Force	Work-to-Cut	Cutting Force	Toughness	Failure Strain	Firmness	Chewiness
CV compression	0.4324	0.9173	-	-	-	-	-
CV sensory	-	-	-	-	-	0.4492	-0.9999
CV extension	-	-	0.9574	0.8633	0.8043	-	-
CV sensory	-	-	-	-	-	0.6266	-0.9807

Table V. First standardized canonical coefficients of textural parameters for relevant canonical variates

Canonical Variate	Compression Test		Tensile Test			Sensory Evaluation	
	Cutting Force	Work-to-Cut	Cutting Force	Toughness	Failure Strain	Firmness	Chewiness
CV compression	0.3984	0.9023	-	-	-	-	-
CV sensory	-	-	-	-	-	-0.0163	-1.0074
CV extension	-	-	1.3351	-0.6536	0.3558	-	-
CV sensory	-	-	-	-	-	0.2205	-0.8788

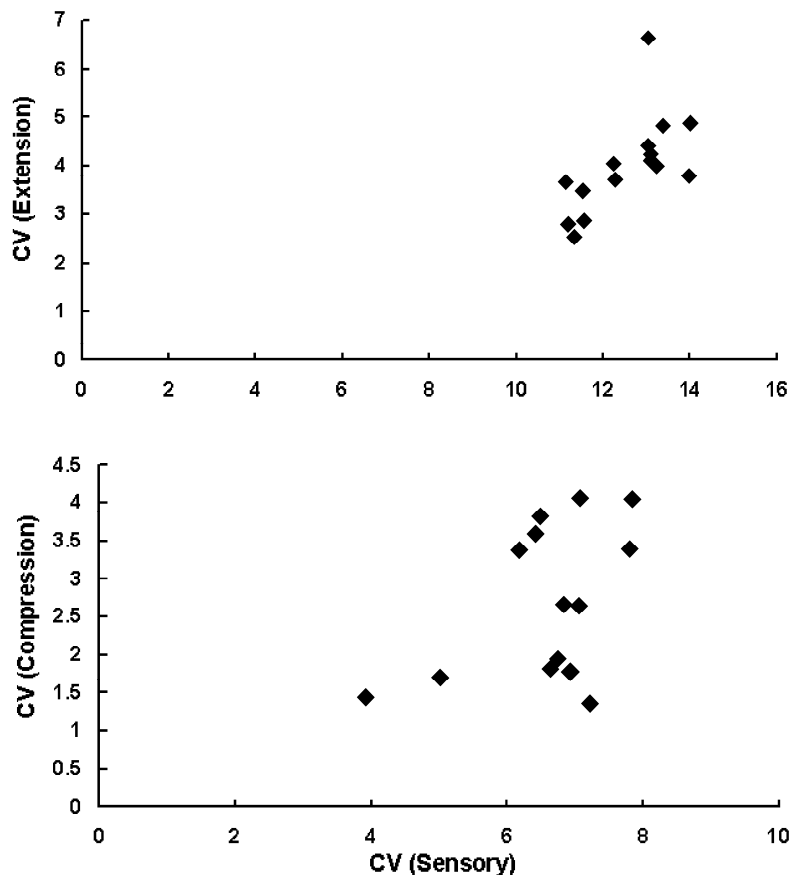


Fig. 6. Canonical correlation analysis of parameters of three groups (tensile test, compression test, and sensory evaluation), showing canonical variates (CV sensory:CV extension, CV sensory:CV compression) of samples in the first canonical variates' space.