

# Measurement of Cooked Noodle Stickiness Using a Modified Instrumental Method

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## ABSTRACT

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Stickiness of cooked noodles, generally defined as a maximum force in tension after compression, depends on the compression force, contact area, and physical properties of the noodles. In the conventional method of measuring stickiness, only compression force was set as a standard, neglecting the other probable influencing factors. A modified method was developed for measuring contact area between noodles and a probe, in addition to the compression force. Four specimens with varying starch contents (0, 30, 60, and 90%) were tested to evaluate the new method for measuring cooked noodle stickiness. Contact area calculated from the displacement of probe at the compression condition was not consistent among the noodle samples. A corrected stickiness and a corrected compression force were defined as a simple stickiness directly measured for the contact area and the compression force measured for the contact area, respectively. This method proved to be a more effective means in

differentiating the stickiness among noodle samples (than using just compression force factors). The order in the corrected stickiness magnitudes among the noodles was consistent regardless of specimen amount used in the measurements, whereas that of the simple stickiness was inconsistent when different size samples were used. The corrected compression force estimated from a fixed simple compression force, which is a true compression stress, varied among the noodles. Accordingly, the corrected compression force was a more accurate criteria for stickiness measurements than was the simple compression force, which subjects the specimens to only differences in compression for stickiness comparison. The corrected stickiness results showed greater relationship to sensory stickiness and starch content than the simple stickiness measurement.

Characteristics of Asian noodles and pasta products, such as color, cooking properties, noodle texture, and taste, are important factors affecting consumer acceptance and product quality (Moss 1971; Nagao et al 1977; Dexter et al 1979; Oh et al 1985; Preston et al 1986; Rho et al 1988; Toyokawa et al 1989; Crosbie 1991; Konic et al 1992). Stickiness is one of the important factors affecting texture properties of pasta and noodle products. The stickiness in the context of noodles has the same meaning as the technical term tackiness used in adhesives technology (Gay and Leibler 1999), which is a force required to separate two bodies. Nonsticky texture of cooked spaghetti is desirable for consumer preference (Dexter et al 1983a,b). Guan and Seib (1994) reported that various types of noodles and spaghetti may differ in internal firmness and elasticity, but their surface must be smooth and free of stickiness. Thus, stickiness measurement becomes important in evaluating the quality of cooking properties of noodles and pasta products.

The instrumental methods developed for determining stickiness could explain the sensory characteristics of the noodle products, but were still insufficient for full considerations. Dexter et al (1983b) measured pasta stickiness by using the modified Grain Research Laboratory (GRL) compression tester for stickiness of bread crumbs. This study indicated, over a fairly wide range, that stickiness values of cooked spaghetti were dependent on compression force. Stickiness values decreased when pressure dropped to <2,500 N/m<sup>2</sup>, possibly because of uneven surface contact between the plunger and the cooked spaghetti. In contrast, cooked spaghetti stickiness increased when pressure rose to >12,500 N/m<sup>2</sup>, possibly due to deformation during compression. Dexter et al (1983b) concluded that a median of 5,200 N/m<sup>2</sup> was the most suitable compression force for stickiness measurement. Guan and Seib (1994) developed an apparatus for measuring noodle stickiness to enhance conditions for a test of

constant contact area. Noodle strains were compressed and squeezed under contact surface of a jaw-type multifaced probe. Change in the area squeezed out of the probe bottom surface in a crosswise direction was eliminated from the contact area, but that squeezed in a longitudinal direction was still reflected in a change in the contact area. The contact area was still not completely considered in noodle stickiness measurement, which is important in measuring stickiness.

Accordingly, the cooked noodle stickiness, defined as a maximum force in tension after compression, is attributed to the contact area, compression force, and physical properties of the noodles. Hypothesizing that the contact area between noodles and a probe could be analyzed, an improved instrumental method for noodle stickiness was studied to define and evaluate the stickiness for contact area and the compression force for contact area.

## MATERIALS AND METHODS

### Materials

A commercial noodle flour sample obtained from Daesun Flour Mills Co. in Seoul, Korea, was used in this study to make the dried noodles for stickiness measurement. The flour sample included a mixture of 65% hard red spring wheat and 35% soft white wheat harvested in 1998 in the United States. Protein and ash contents of flour sample were 9.33 and 0.414% on a 14% moisture basis, respectively. Potato starch (Joongang Chemical Co., Seoul, Korea) was added at 30, 60, and 90%, respectively, on a 100 g flour basis.

### Proximate Composition Analysis

Moisture content was determined by Approved Method 44-15A (AACC 2000). Flour ash content was determined by the muffle furnace method (Approved Method 08-01); and flour protein content was analyzed by the Kjeldahl nitrogen procedure (Approved Method 46-10), using 5.7 to convert nitrogen to protein.

### Preparation of Noodles

A pilot-scale laboratory noodle machine (Seoju Engineering Co., Seoul, Korea) was used for the preparation of the dried noodles. Dried noodles were made in the laboratory using 100 parts of flour, 35 parts of distilled water, and two parts of salt. Ingredients were mixed in a mixer and a salt solution was added to the flour for 30 sec with 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

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for 15 min to distribute water uniformly throughout the flour particles. The dough was passed 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, in the same direction. The final sheeted noodle dough was cut into strips 1.7 mm wide and 60 cm long. Noodles were dried for 10 hr at 25 ± 1°C with of 54–56% rh in a cabinet. The dried noodles were cut into 30-cm lengths. The short strands (20 g) were boiled in a container with 500 mL of distilled water for 5 min and cooled in tap water for 30 sec. Cooked noodles were drained on a plastic screen with apertures of 0.5 mm for 1 min and measured for stickiness. The whole process was done in duplicate.

### Stickiness Measurement

A texture analyzer (TA-XT2, Stable Microsystems, England) was used in a hold-distance mode with a cylindrical probe (45 mm diameter). The test speed was 0.1 mm/sec, and pretest and posttest speeds were 3.0 mm/sec. Holding time at maximum compression was 0.1 sec. Three levels of compression force were applied: 300, 400, and 500 g-force. Casual surface water of the cooked noodles was eliminated by rolling twice on a filter paper (Whatman No. 2). Specimens of a strand of the cooked noodles were weighed (0.25, 0.30, 0.35, and 0.40 g, respectively) and placed unfolded on the platform for the compression and retraction test.

During compression, the contact area between noodles and bottom surface of probe changes with height. It was assumed that the change in the contact area is directly proportional to the height because the final state of the specimen geometry after compression becomes nearly a very wide and shallow slab. The contact area between noodles and bottom surface of probe (Fig. 1) was calculated as:

$$\text{Contact area} = \text{specimen mass}/(\text{density} \times \text{height}) \quad (1)$$

where the density was measured according to the Archimedes principle (Kane and Sternheim 1983):

$$\text{Density} = \text{noodle mass in air}/\text{noodle volume} \quad (2)$$

$$\text{Noodle volume} = (\text{noodle mass in air} - \text{noodle mass in water})/\text{water density} \quad (3)$$

Corrected stickiness and corrected compression force were estimated as for contact area:

$$\text{Corrected stickiness} = \text{simple stickiness}/\text{contact area} \quad (4)$$

$$\text{Corrected compression force} = \text{compression force}/\text{contact area} \quad (5)$$

where the simple stickiness is a directly measured force in the compression and retraction test.

For this study in the corrected method, the effect that different kinds of noodles with different specimen amounts had on the stickiness and contact area were observed in four types (Cases) of experiments. In Case I, specimens of all the same amount, 0.3 g, were used for four kinds of noodles (0, 30, 60, and 90% starch contents), respectively (Table I). In Case II, 0.25, 0.30, 0.35, and 0.40 g of specimens were used with 0, 30, 60, and 90% starch contents, respectively. In Case III, 0.40, 0.35, 0.30, and 0.25 g of noodle samples were weighed for 0, 30, 60, and 90% starch content. In Case IV, 0.35, 0.40, 0.25, and 0.30 g of noodle specimens were used for 0, 30, 60, and 90% starch content, respectively. Surfaces of the probe bottom and platform were cleaned at every measurement interval. The stickiness measurements were made in five replicates where the tests were performed twice in each case.

### Sensory Evaluation

Ten highly trained panelists from the Department of Food Science and Technology at Dongguk University in Seoul, Korea, participated in the sensory evaluation for the cooked noodle stickiness. Noodles were prepared in the same manner before the stickiness measurements and evaluated with the method described by Dexter et al (1983b).

### Statistical Analysis

The general linear model (GLM) procedure (SAS Institute, Cary, NC) was used to perform analyses of variance (ANOVA) to assess data variability. The least significant difference (LSD) test was performed to determine statistical differences between means

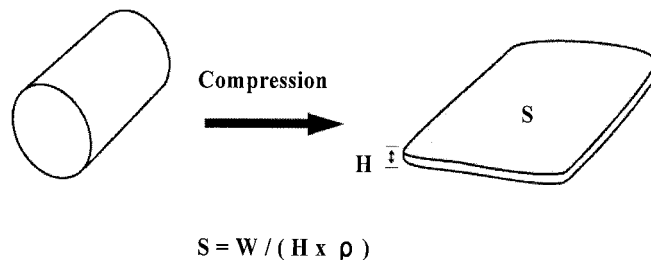


Fig. 1. Contact area (S) of cooked noodles showing weight of cooked noodles (W); height of cooked noodles after compression (H); and density of cooked noodles ( $\rho$ ).

TABLE I  
Contact Area (mm<sup>2</sup>) of Cooked Noodle Specimens in Simple Stickiness Measurements

Case <sup>a</sup>	Potato Starch Content <sup>b</sup>	Compression Force (g-force)		
		300	400	500
I	A	0.1364c <sup>c</sup>	0.1454bc	0.1550b
	B	0.1355bc	0.1420c	0.1628ab
	C	0.1435ab	0.1525ab	0.1649a
	D	0.1455a	0.1568a	0.1664a
II	A	0.1270c	0.1241c	0.1264d
	B	0.1355c	0.1420c	0.1584c
	C	0.1590b	0.1710b	0.1733b
	D	0.1864a	0.1943a	0.2019a
III	A	0.1710a	0.1807a	0.2001a
	B	0.1569b	0.1711b	0.1653b
	C	0.1396c	0.1446c	0.1607b
	D	0.1213d	0.1387d	0.1392c
IV	A	0.1558b	0.1707a	0.1696b
	B	0.1869a	0.1529bc	0.1671b
	C	0.1286c	0.1594b	0.1908a
	D	0.1473bc	0.1477c	0.1678b

<sup>a</sup> Specimen weight with each starch content: Case I (0.3, 0.3, 0.3, 0.3 g); Case II (0.25, 0.3, 0.35, 0.4 g); Case III (0.4, 0.35, 0.3, 0.25 g); Case IV (0.35, 0.4, 0.25, 0.3 g).

<sup>b</sup> A, B, C, D = 0, 30, 60, 90%.

<sup>c</sup> Values followed by the same letter in the same column are not significantly different ( $P < 0.05$ ).

when ANOVA indicated significant differences in means ( $P < 0.05$ ). Pearson correlation coefficients were calculated as a measure of association of simple stickiness and corrected stickiness parameters with sensory stickiness and starch content.

## RESULTS AND DISCUSSION

### Contact Area

The density used in calculation of the contact area was measured as 1.129, 1.128, 1.135, and 1.138 g/mL for noodles of 0, 30, 60, and 90% starch contents, respectively. The results in Case I appeared to be similar to results that would be obtained by conventional stickiness measurement methods. However, the contact area at each fixed compression force condition was not consistent with the types of noodles, although the same amounts of specimens were used (Table II). This indicated that simple stickiness was generated by a different stress (force for contact area) in spite of the same compression force condition. This may also imply that it is necessary to

compensate for differences in the contact area when using the conventional method. In all cases (I, II, III, and IV), the contact area increased as the compression force increased and the amount of specimens increased. In Case I, the largest contact area was found in specimen D (90% starch content), while the smallest was observed in specimen A (0% starch content). This was because the starch produced soft noodles and so the noodles with high starch content were squeezed more by the compression (Dexter et al 1983b). The differences in Cases II, III, and IV were possibly due to which effect on the contact area was more dominant, starch content or specimen amounts. Specimen amounts might also have caused changes in contact area, that is, wider contact area with a larger specimen amount.

Meanwhile, it was known that surface roughness of either specimen or solid probe, and air bubbles at the interface affect the stickiness and this was attributed to the restriction of true contact area (Gay and Leibler, 1999). But in this study, such effects were neglected compared with those produced by the differences in the compression force and the consistency, amount, and height of the specimens.

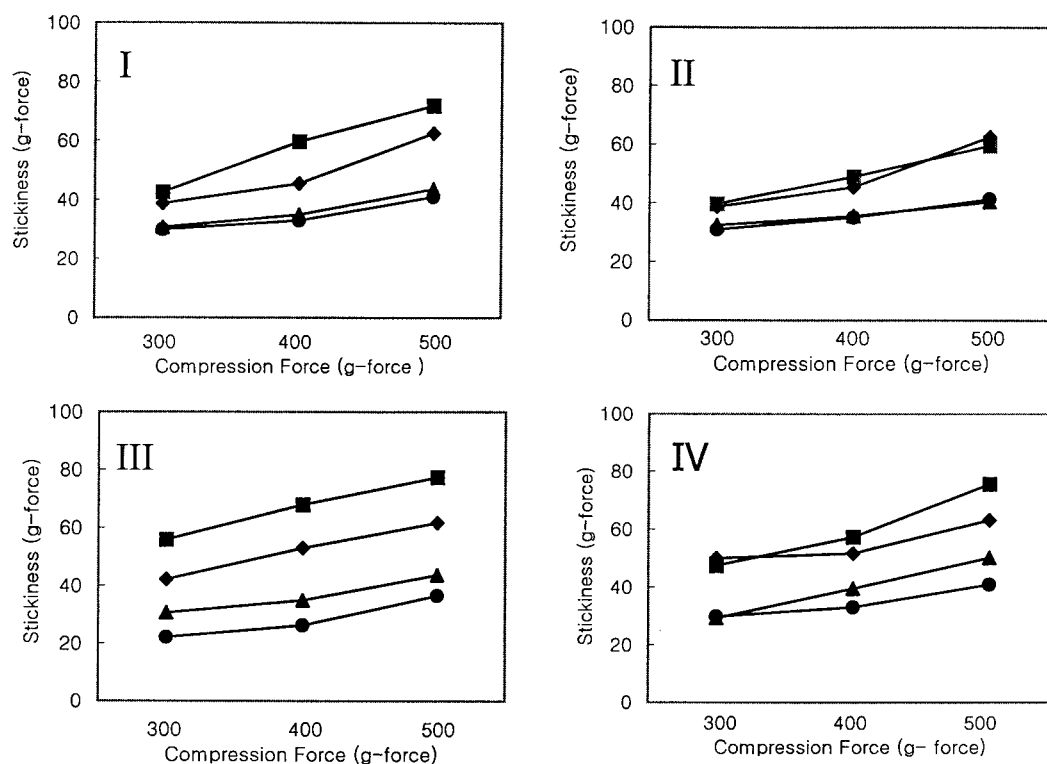


Fig. 2. Relationship between simple stickiness and compression force in Cases I-IV. Noodles with potato starch contents (■, ◆, ▲, ● = 0, 30, 60, 90%).

TABLE II  
Correlation Coefficients of Simple Stickiness and Corrected Stickiness of Cooked Noodles with Sensory Stickiness and Starch Content

Case <sup>a</sup>	Compression Force (g <sub>r</sub> )	Simple Stickiness vs. Sensory Stickiness	Simple Stickiness vs. Starch Content	Corrected Stickiness vs. Sensory Stickiness	Corrected Stickiness vs. Starch Content
I	300	0.89	-0.96	0.99	-0.97
	400	0.96	-0.94	0.99	-0.97
	500	0.92	-0.93	0.94	-0.98
II	300	0.94	-0.95	0.98	-0.98
	400	0.95	-0.87	0.99	-0.95
	500	0.83	-0.74	0.97	-0.92
III	300	0.98	-0.99	0.99	-0.99
	400	0.97	-0.98	0.97	-0.99
	500	0.96	-0.95	0.99	-0.96
IV	300	0.88	-0.81	0.98	-0.99
	400	0.94	-0.88	0.96	-0.93
	500	0.98	-0.99	0.99	-0.97

<sup>a</sup> Specimen weights with 0, 30, 60, 90% starch contents, respectively. Case I (0.3, 0.3, 0.3, 0.3 g); Case II (0.25, 0.3, 0.35, 0.4 g); Case III (0.4, 0.35, 0.3, 0.25 g); Case IV (0.35, 0.4, 0.25, 0.3 g).

### Stickiness

As previously indicated, stickiness assessment needed to be generated under fair conditions, that is, with uniform size of contact areas, to differentiate the force in retraction according to specimen physical properties. In simple stickiness measurements (Fig. 2), differences among the noodles were observed but minimal in Case I, with the

same amount for each specimen. In Cases II and IV, even the order of simple stickiness magnitude among the noodles varied with compression force. This was because the specimen amount used was different for each specimen, resulting in different sizes of contact areas, in spite of starch contents of 0, 30, 60, 90% in the samples. In Case III, the differences among the noodles were apparent because noodles with

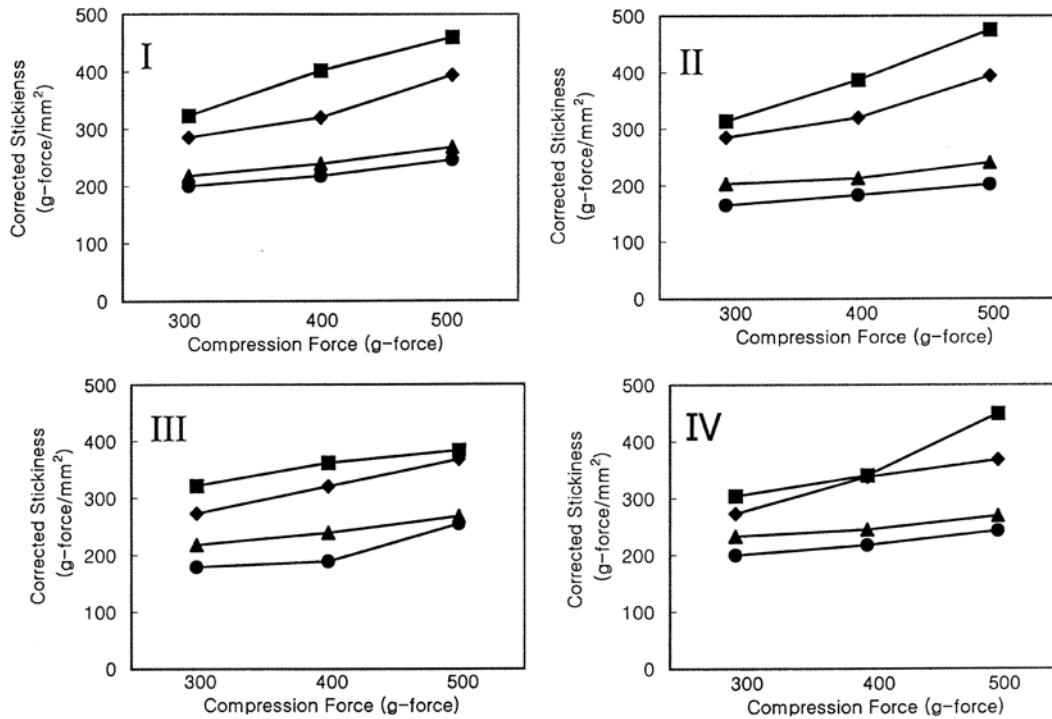


Fig. 3. Relationship between corrected stickiness and compression force in Cases I–IV. Noodles with potato starch contents (■, ◆, ▲, ● = 0, 30, 60, 90%).

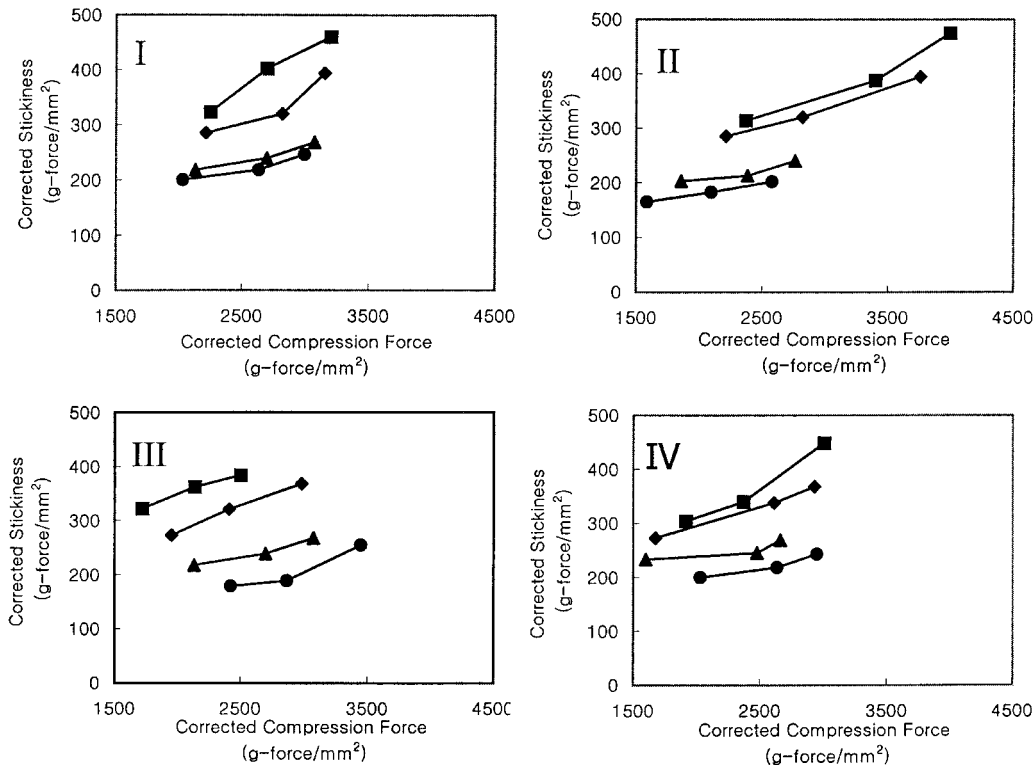


Fig. 4. Relationship between corrected stickiness and corrected compression force in Cases I–IV. Noodles with potato starch contents (■, ◆, ▲, ● = 0, 30, 60, 90%).

higher starch content had less simple stickiness as shown in Case I and smaller contact area due to smaller specimen amount used (Table II). Likewise, the specimen amount affected the contact area and, hence, the simple stickiness magnitudes; a specimen amount variation possible in the experiments could have also caused the stickiness variation.

In corrected stickiness, such as the simple stickiness for contact area (Fig. 3), the differences among the noodles became clearer than those before correction, as in Case I. Furthermore, in the other cases, the improved method showed more apparently that the order in the magnitudes of corrected stickiness among the noodles was kept consistent regardless of the specimen amount. This indicated that the corrected method could be used as an effective means for differentiating stickiness among noodles, avoiding experimental error possible when trying to keep the noodle specimens the same amount.

In Case IV for corrected stickiness, however, there were still two odd points observed for noodles of starch content of 0 and 30% (Fig. 3). This implied that another factor must be considered in order to overcome this inconsistency. So the compression force was corrected as a stress, because the compression force for contact area was possibly different if the contact area was not consistent, even under the same compression force conditions. Thus, the compression force for contact area that caused the stickiness was not consistent, as shown in Fig. 4. This indicated that the condition of the compression force was not substantially constant to generate the noodle stickiness. Therefore, the stickiness of noodles needed to be compared at fixed values of the corrected compression force, not the simple compression force. As a result, differences in cooked noodle stickiness could be perceived to a greater extent than before correction of compression force, including enhancement of the two odd points shown in Fig. 3. Therefore, it seems necessary to define the compression condition properly as corrected compression force when comparing stickiness. Dexter et al (1983b) remarked about the tolerable range of the compression force in stickiness evaluation. The corrected compression force in this study, as well as the concept of Dexter et al (1983b), could be used for defining the most suitable compression conditions in stickiness measurements.

#### Relationships Between Cooking Quality and Stickiness

Comparison with starch content and sensory stickiness is important for evaluating the effectiveness of the corrected stickiness as a new approach because the starch affects the noodle stickiness (Dexter and Matsuo 1979; Guan and Seib 1994). The sensory stickiness might be an authentic property of the noodle stickiness. The simple stickiness and corrected stickiness had positive correlations with sensory stickiness and negative correlations with starch content (Table II). Corrected stickiness showed higher correlation coefficients than the simple stickiness. The improvement in correlation coefficients could imply that the corrected stickiness method is another development in noodle stickiness research. Consequently, the corrected method tested in this study could be a useful means for measuring cooked noodle stickiness.

#### CONCLUSIONS

This study demonstrated the effectiveness of corrected stickiness and corrected compression force of cooked noodles, considering the

amount of contact area when measuring stickiness. The corrected stickiness method appeared to be useful for differentiating cooked noodle stickiness, as compared with the simple stickiness method. Furthermore, this corrected stickiness method was useful when various noodle weights were examined or an experimental error in weighing the specimen was possible. Corrected compression force could be a way to increase stickiness and be a more accurate way to differentiate the stickiness among noodles, as well as the corrected stickiness. Consequently, this new approach could be beneficial in understanding the phenomena of cooked noodle stickiness.

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