Noodles. I. Measuring the Textural Characteristics of Cooked Noodles[1]

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ABSTRACT

Cereal Chem. 60(6):433-438

The Instron Universal Testing Instrument was used to measure certain textural characteristics of cooked noodles. Cooked noodles were cut or compressed across their long dimension. When optimum cooking time and a subsequent standing period of 10 min at 25°C were used, maximum cutting stress and resistance to compression were reproduced with coefficients of variation of less than 5%. The maximum cutting stress and resistance to compression were significantly different for noodles made from eight wheat flours. When correlated with sensory evaluation of firmness and chewiness of noodles, maximum cutting stress and resistance to compression, respectively, gave correlation coefficients of 0.888 ($P < 0.01$) and 0.848 ($P < 0.01$). Noodles made from four flours under identical laboratory conditions varied in thickness after cooking, from 2.25 ± 0.04 mm to 2.85 ± 0.07 mm. The maximum cutting stress and the resistance to compression changed linearly with thickness, and the rate of change was the same for all four noodles.

Many types of noodles are produced throughout the world. In their simplest form, wheat noodles are a type of pasta prepared from a dough containing flour, water, and salt. The standard of identity for noodles in the United States specifies that they be made from wheat dough containing eggs, and the source of wheat is usually durum. The dried noodles must contain $\geqslant 87\%$ solids and $\geqslant 5.5\%$ egg solids (Code of Federal Regulations 1981). Usually, noodles made in Asian countries do not contain eggs, although the use of eggs depends greatly on the type of noodle and the specific region of Asia. Chinese wheat noodles are made from wheats other than durum and contain sodium and potassium carbonate in place of much of the sodium chloride. Starch noodles contain only starch, principally from mung beans. Other ingredients found in oriental noodles are sodium silicate, sodium polyphosphate, lecithin, fat, ground vegetables, and a variety of flours, starches, and gums.

Besides the ingredients, various processes also contribute to the diverse types of noodles, which differ primarily in moisture and degree of precooking (Fig. 1). Fresh (raw) noodles contain $\sim 35\%$ moisture (w.b.), wet noodles cooked before marketing contain $\sim 52\%$ moisture, and dry noodles $\sim 10\%$. Instant noodles are steamed and then dried or deep-fat fried and contain $\sim 8\%$ moisture. Fried noodles contain $\sim 20\%$ lipid.

To begin our program of determining the effect of flour properties on noodle quality, we chose the dry noodle because of its simple formula and storage stability. Other investigators have reported on the quality of the dry noodle (Bean et al 1974, Cheigh et al 1976, Lii and Chang 1981), fried noodle (Okada 1971), and fresh (raw) noodle (Jeffers et al 1979, Oda et al 1980).

The quality of the dry noodle is judged by its color, symmetry, cooking quality, and texture. The noodle should have a white opaque appearance and be free of checking, although regional consumer preferences dictate that a yellow food dye sometimes be added to give a yellow noodle rather than a white noodle. It should cook as quickly as possible, remain firm and not lose solids in the cooking water, and should not become sticky and soggy when standing after cooking. Much information is needed to determine the quality factors in flour that govern the characteristics of noodles.

The texture of a cooked noodle is perceived by the resistance of the noodle to chewing and by the mouthfeel of its surface. Several instruments have been used to measure noodle texture, including the General Foods Texturometer (Chang and Lee 1974, Cheigh et al 1976), Autograph S-100 (Lii and Chang 1981), Texturecorder (Nielsen et al 1980), and a viscoelasticity meter (Okada 1971). No detailed information has been reported on the factors affecting measurement of noodle texture.

Pasta and noodles are closely related products, and several methods have been developed to measure the strength of cooked spaghetti. Matsuo and Irvine (1969, 1971, 1974) devised an instrument that measured tenderness, compressibility, and recovery of cooked spaghetti. Walsh (1971) measured the firmness of cooked spaghetti with the Instron Universal Testing Instrument. Voisey and Larmond (1973) and Voisey et al (1978) used the Ottawa texture-measuring system and showed that the cutting rate and the standing period after cooking were critical in measuring the texture of spaghetti. They also noted that the variation in the diameter of cooked spaghetti affected texture measurements.

Our objective in this study was to develop an instrumental method to determine the texture of dry noodles after cooking. The extent to which the texture is related to other characteristics, such as cooking loss, stickiness, and sogginess, is under investigation.

MATERIALS AND METHODS

Noodles

Three commercial samples of dry noodles were obtained from Korea, Japan, and Singapore. Five other samples were made in the laboratory from five flours (Table I), using 100 parts of flour, 30–33 parts of water, and two parts of salt. The proper water absorption was determined by the appearance and handling properties of a dough sheet. Insufficient water gave a nonuniform sheet, whereas excess water gave a sheet that was too extensible. Mixing was done with a Hobart N-50 mixer fitted with a flat beater agitator (The Hobart Mfg. Co., Troy, OH). With the mixer speed on position 1,

TABLE I
Analysis of Flours and Noodles[a]

	Flour			Uncooked Noodle				Cooked Noodle		
	M	Pr	Ash	M	Pr	Ash	CT	M	Pr	Ash
Noodle	(%)	(%, d.b.)		(%)	(%, d.b.)		(min)	(%)	(%, d.b.)	
SWF 1[b]	13.1	9.8	0.59	10.1	9.3	2.67	10	72.5	9.4	0.85
SWF 2[b]	12.7	10.2	0.44	10.6	10.1	2.46	12	70.3	10.0	0.65
HWF 1[b]	13.9	13.3	0.50	10.2	12.7	2.56	15	72.5	13.4	0.51
HWF 2[b]	14.0	13.0	0.46	9.7	12.6	2.55	14	71.5	13.5	0.54
HWF 3[b]	12.7	15.7	0.60	9.9	15.2	2.66	17	73.0	16.0	0.66
COM 1[c]	···	···	···	11.4	10.4	0.99	7	72.2	10.8	0.46
COM 2[c]	···	···	···	10.4	11.3	4.02	10	69.8	11.4	0.96
COM 3[c]	···	···	···	10.4	9.3	5.69	9	69.2	9.6	1.16

[a] Abbreviations: M = moisture, wet basis; Pr = protein; d.b. = dry basis; CT = optimum cooking time; SWF 1 = soft wheat flour, Fisher Mills Inc., Seattle, WA; SWF 2 = soft wheat flour, Mennel Milling Co., Fostoria, IA; HWF 1 = hard wheat flour, KSU pilot mill, Manhattan, KS; HWF 2 = hard wheat flour, Ross Industries, Wichita, KS; HWF 3 = hard wheat flour, General Mills Inc., Minneapolis, MN.

[b] Laboratory-processed noodle.

[c] Commercial noodle.

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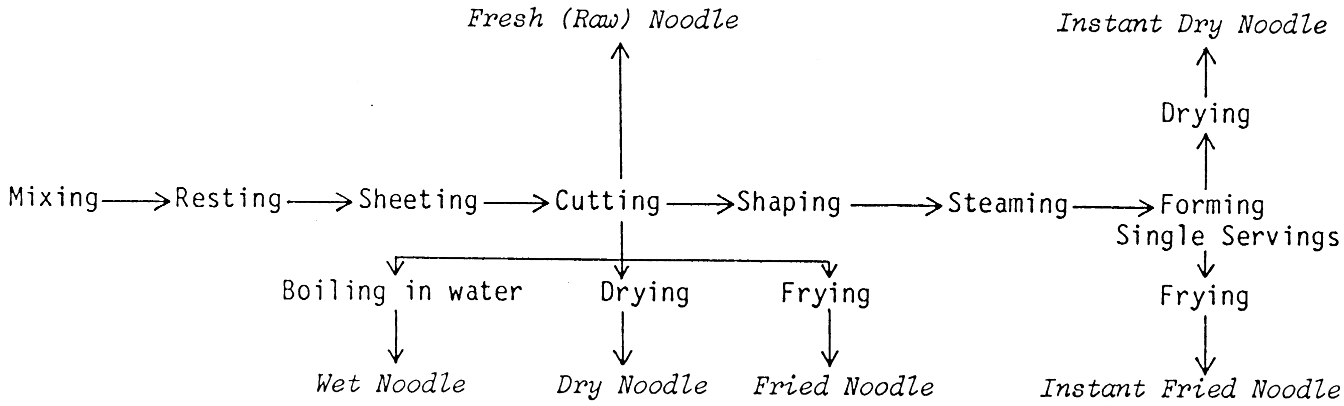

Fig. 1. Oriental noodles classified by moisture and degree of precooking.

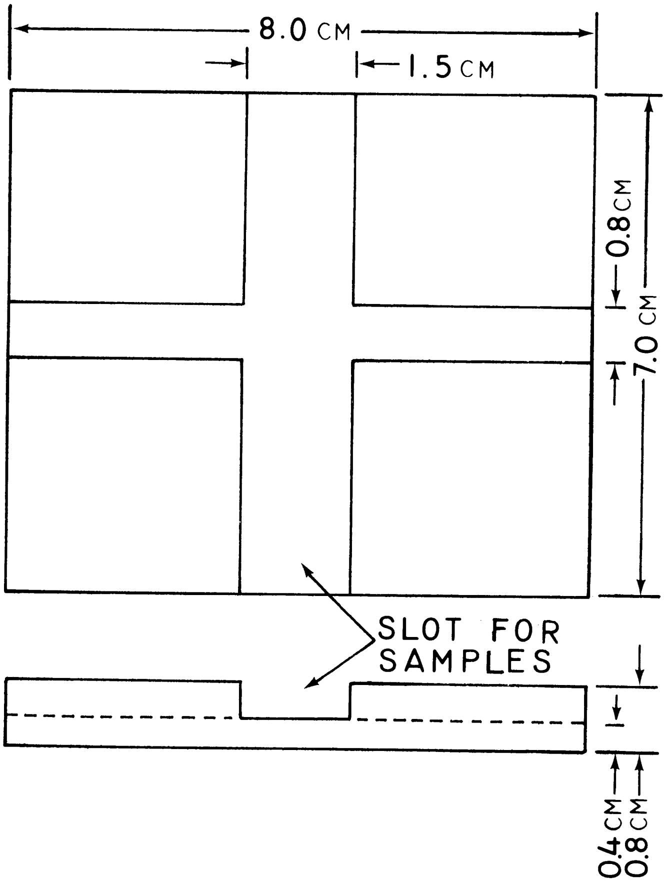

Fig. 2. Sample holder.

brine was added to flour over a period of 30 sec. Mixing was continued an additional 30 sec on speed 1, and then 4 min on speed 2. After mixing, the bowl contained nodules of dough with diameters ≤3 mm. The nodules were pressed into an initial dough sheet by passage through the rolls (roll diameter = 18 cm) of the Ohtake laboratory noodle machine (Ohtake Noodle Machine Mfg. Co. Ltd., Tokyo, Japan). The dough was then allowed to rest in a plastic bag at room temperature for 30 min. Seven sheeting steps were used, starting from the initial gap setting of 4.0 mm and ending at 1.3 mm. A 15% reduction in gap setting was used for successive sheeting steps. The final dough sheet had a thickness of approximately 1.5 mm. Immediately after sheeting, the dough sheet was cut into 2.5 mm-wide noodle strips, and strips were hung to dry in a Demaco dryer (De Francisci Machine Corp., Brooklyn, NY). The drying temperature was held constant at 45°C while humidity was gradually decreased from 85% to 65% over a 10-hr period.

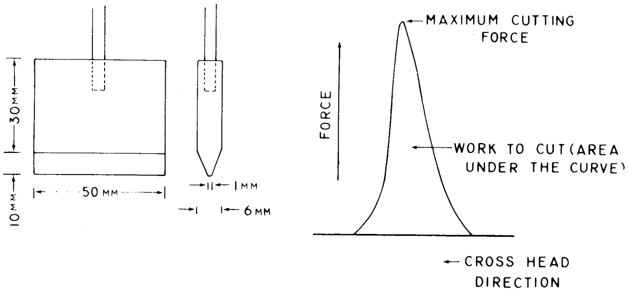

Fig. 3. Left, attachment used for cutting test; **right,** Instron curve.

Noodles of Various Thicknesses

Thickness of dry noodles was varied between 1.0 and 2.8 mm in twenty samples of noodles made from four of the five flours. Different thicknesses of noodles were prepared by adjusting the thickness of the initial dough sheet. Each noodle sample received seven sheetings with a reduction setting of 15% in the gap of the rolls for each step.

Noodle Cooking

Noodles (20 g) were cooked in 1,000 ml of boiling tap water. The water was held at a gentle boil (98.0 ± 0.5°C), and the noodles stirred occasionally. The optimum cooking time, which was the time required for the white core in the noodle strand to disappear, was determined by squeezing noodle strands between a pair of Plexiglas™ plates. After cooking was complete, the noodles were cooled in running tap water for 1 min, drained, placed in polyethylene bags, and allowed to stand for predetermined time periods at 25°C.

Instron Tests

The Instron Universal Testing Instrument (model 1130, Instron Corp., Canton, MA) was fitted with a 2,000-g compression cell. Before it was measured with an Instron, the combined width of three cooked noodle strands was measured with a caliper. The thickness of a noodle was determined from its force-distance curve on the Instron.

The cutting test was performed at a crosshead speed of 5 cm/min and a chart speed of 50 cm/min. Three strands of cooked noodles were placed in the sample holder (Fig. 2) and cut crosswise by the Plexiglas blade (Fig. 3) attached to the crosshead of the Instron. From force-distance curves, the maximum cutting stress and the work to cut per unit area were determined. The maximum cutting stress, which is in units of grams per square millimeter, was calculated by dividing the peak height by the initial blade contact area. The work to cut per unit area, which is in units of grams per millimeter, was calculated by dividing the area under the curve by the initial blade contact area. The area under the curve was measured by a compensating polar planimeter (Lasico Inc., Los Angeles, CA).

The compression and recovery tests were done using an attachment having a contact surface of 3.5 × 50 mm (Fig. 4). The crosshead and chart speeds were set at 2.5 cm/min and 25 cm/min, respectively. Three strands of cooked noodle were placed in the sample holder and compressed crosswise to a stress of 1.3 kg/cm^2, at which point the compression force was removed. From the compression-recovery curve (Fig. 4), the compression slope per unit area (units = g/mm^3), resistance to compression (percent), and recovery (percent) were measured. The compression slope per unit area was calculated by dividing the tangent on the curve (Fig. 4) at 50% compression by the blade contact area. The resistance to compression was defined as 100 times the ratio of the retained thickness, initial thickness minus the compressed distance (A in Fig. 4), to the initial thickness of the cooked noodle. The recovery was defined as 100 times the ratio of the distance recovered (C in Fig. 4) to the distance of compression (B). Distance C was used to eliminate the inconsistency in measuring the recovered distance caused by irregular tailing of the curve. Distance B was used to match with distance C.

Sensory Tests

The firmness and chewiness of cooked noodles were evaluated by eight trained panelists. Firmness was judged as the force required to bite through a noodle strand between the molar teeth. Chewiness was defined as the length of time (seconds) required to masticate 10 g of cooked noodle at the rate of one chew per second to a consistency small enough to swallow. The firmness of a sample was scored by placing a mark on a structured line scaled from 1 to 10. The higher the score, the firmer the noodle sample. One sample of noodle, which was assigned a value of 4 on the firmness scale, was provided as a reference material to the panelists. Training sessions were held until panel members could identify the same sample that was coded differently in a session.

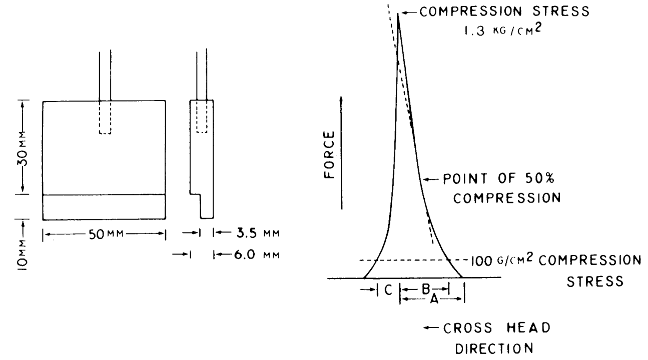

Fig. 4. Left, attachment used for compression and recovery tests; **right,** A = the compressed distance used for compression test, B and C = the compressed and recovered distances, respectively, used for recovery test.

TABLE II
Texture Variables for Optimally Cooked Noodles Measured by the Instron on Five Different Days

Noodle[a]	Maximum Cutting Stress (g/mm^2)	Work to Cut (g/mm^1)	Compression Slope (g/mm^3)	Resistance to Compression (%)	Recovery (%)
SWF 1	20.8	22.8	7.46	23.4	23.0
	21.8	25.0	7.70	24.0	25.0
	22.2	23.8	7.70	22.7	22.5
	21.3	23.1	7.94	23.0	25.5
	22.7	24.4	8.18	21.0	23.4
Mean	21.76	23.82	7.80	22.82	23.88
CV (%)	3.4	3.8	3.5	4.9	5.5
HWF 1	27.8	32.9	8.13	30.0	43.0
	28.7	30.3	8.36	29.5	44.5
	29.1	31.5	8.81	28.4	42.6
	27.8	32.9	8.13	29.0	40.5
	27.4	30.0	8.70	32.0	40.0
Mean	28.16	31.52	8.43	29.78	42.12
CV (%)	2.5	4.4	3.8	4.6	4.4

[a] SWF 1 = Soft wheat flour, Fisher Mills Inc., Seattle, WA. HWF 1 = Hard wheat flour, KSU pilot mill, Manhattan, KS.

RESULTS AND DISCUSSION

The five variables—maximum cutting stress, work to cut, compression slope, resistance to compression, and recovery of the cooked noodles made from a soft and a hard wheat flour (SWF 1 and HWF 1)—gave good reproducibility; coefficients of variations of the variables measured 10 min after cooking on five different days were between 2.5 and 5.5% (Table II).

Eight samples of optimally cooked noodles were tested on the Instron. The data in Table III show that each factor varied considerably for the various samples of noodles, which indicated that the parameters were sensitive to textural differences.

Instron Readings Correlated with Sensory Results

The Instron variables were compared with the results of sensory evaluation by eight trained panelists. For experimental convenience, cooked noodle samples were tested 30 min after standing for both the Instron measurements and sensory

TABLE III
Texture Variables for Samples of Noodles Cooked to Optimum and Allowed to Stand 10 Min

Noodle[a]	Maximum Cutting Stress (g/mm^2)	Work to Cut (g/mm^1)	Compression Slope (g/mm^3)	Resistance to Compression (%)	Recovery (%)
SWF 1	21.8	23.8	7.80	22.0	23.8
SWF 2	26.8	28.9	8.20	32.0	40.9
HWF 1	28.2	31.5	8.43	30.2	42.0
HWF 2	30.5	36.4	7.82	30.0	43.0
HWF 3	43.9	53.4	8.89	42.6	54.2
COM 1	28.4	24.7	12.32	39.5	45.3
COM 2	26.7	25.5	9.63	35.0	42.3
COM 3	25.9	22.4	9.62	30.0	45.0
LSD (P = 0.05)[b]	1.5	1.9	0.28	1.7	1.4

[a] Abbreviations: SWF 1 = Soft wheat flour, Fisher Mills Inc., Seattle, WA; SWF 2 = soft wheat flour, Mennel Milling Co., Fostoria, IA; HWF 1 = hard wheat flour, KSU pilot mill, Manhattan, KS; HWF 2 = hard wheat flour, Ross Industries, Wichita, KS; HWF 3 = hard wheat flour, General Mills Inc., Minneapolis, MN; COM 1, 2, and 3 = commercial noodles.

[b] Least significant difference. Differences between two means exceeding this value are significant.

TABLE IV
Summary of Instron and Sensory Data[a]

	Instron Measurements[b]					Sensory Values	
Noodle	MCS	WTC	CS	RTC	Rec	Firmness[c]	Chewiness (sec)
SWF 1	14.3	14.8	5.3	0	0	2.9	30.2
SWF 2	20.4	20.7	6.0	29.3	30.1	3.7	35.5
HWF 1	20.9	24.8	6.1	27.6	31.0	3.5	32.0
HWF 2	24.0	28.5	5.8	27.2	32.7	4.0	34.0
HWF 3	32.6	45.1	7.0	39.6	49.5	5.9	40.5
COM 1	18.2	15.5	10.4	36.5	51.6	4.4	38.0
COM 2	20.4	20.1	7.7	32.2	36.3	4.2	36.5
COM 3	16.1	14.8	8.5	27.0	38.0	3.0	36.0
LSD (P = 0.05)[d]	1.3	1.8	0.3	1.5	1.6	0.4	1.4

[a] Noodles were cooked to optimum and allowed to stand 30 min.

[b] Abbreviations: MCS = maximum cutting stress (g/mm^2); WTC = work to cut (g/mm); CS = compression slope (g/mm^3); RTC = resistance to compression (%); Rec = recovery (%).

[c] Firmness scale of 1–10, with highest firmness being 10.

[d] Least significant difference. Differences between two means exceeding this value are significant.

evaluation. Table IV summarizes the experimental data, and Table V gives the correlation coefficients calculated between the Instron readings and sensory results.

The maximum cutting stress and the work to cut showed significant positive correlations with sensory firmness, but not with sensory chewiness. The compression slope did not show a relationship with either sensory measurement, but resistance to compression was significantly correlated with sensory firmness ($P < 0.05$) and chewiness ($P < 0.01$). Recovery gave a significant correlation with sensory chewiness ($P < 0.01$).

The relationships between the Instron variables were also examined. Table VI shows that a significant correlation was found between maximum cutting stress and work to cut ($P < 0.01$), and between resistance to compression and recovery ($P < 0.01$). The maximum cutting stress and resistance to compression were more convenient to determine than the work to cut and recovery terms, respectively. Furthermore, the maximum cutting stress correlated well with firmness, and resistance to compression with chewiness (Table V). Maximum cutting stress and resistance to compression were, therefore, preferred as instrumental measures of noodle texture.

TABLE V
Correlation Coefficients Between Instron Variables and Sensory Results

Instron Variable	Firmness	Chewiness
Maximum cutting stress	0.888**[a]	0.615
Work to cut	0.817*[b]	0.488
Compression slope	0.234	0.616
Resistance to compression	0.721*[b]	0.848**[a]
Recovery	0.691	0.878**[a]

[a] **Significant at $P = 0.01$.
[b] *Significant at $P = 0.05$.

TABLE VI
Interrelationship Between Instron Variables[a]

Instron Variable	MCS	WTC	CS	RTC	Rec
MCS	1.0	···	···	···	···
WTC	0.979**[b]	1.0	···	···	···
CS	−0.130	−0.262	1.0	···	···
RCT	0.629	0.479	0.547	1.0	···
Rec	0.540	0.396	0.708*[c]	0.964**[b]	1.0

[a] Abbreviations: MCS = maximum cutting stress (g/mm^2); WTC = work to cut (g/mm); CS = compression slope (g/mm^3); RTC = resistance to compression (%); Rec = recovery (%).
[b] **Significant at $P = 0.01$.
[c] *Significant at $P = 0.05$.

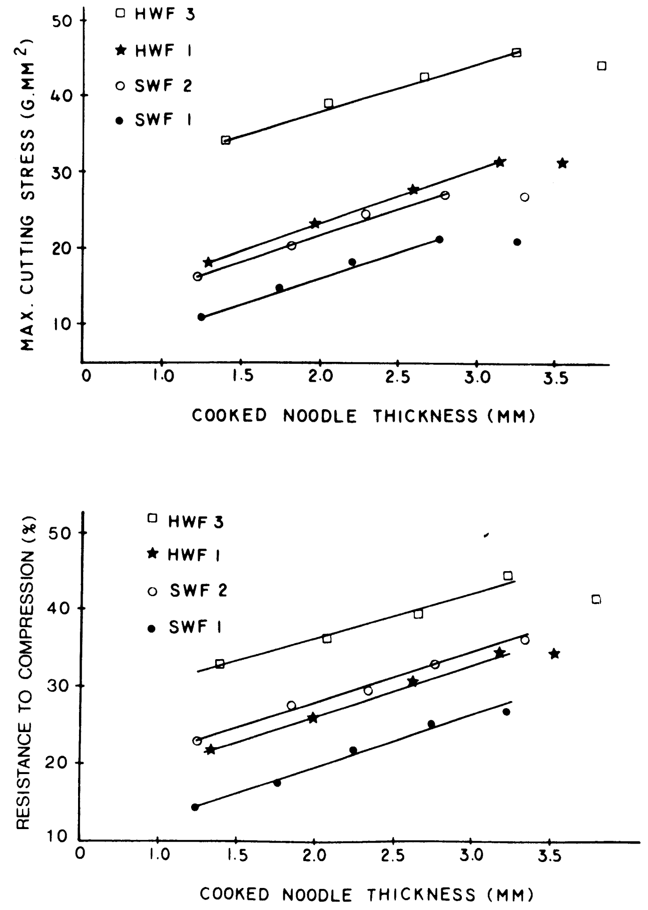

Fig. 5. Effect of noodle thickness on maximum cutting stress and resistance to compression measured 10 min after cooking.

TABLE VII
Variation in Noodle Thickness

Noodle	Uncooked (mm)	Cooked (mm)
SWF 1	1.45 ± 0.04	2.25 ± 0.04
SWF 2	1.65 ± 0.03	2.46 ± 0.04
HWF 1	1.65 ± 0.05	2.52 ± 0.05
HWF 2	1.60 ± 0.05	2.45 ± 0.07
HWF 3	1.80 ± 0.06	2.85 ± 0.07

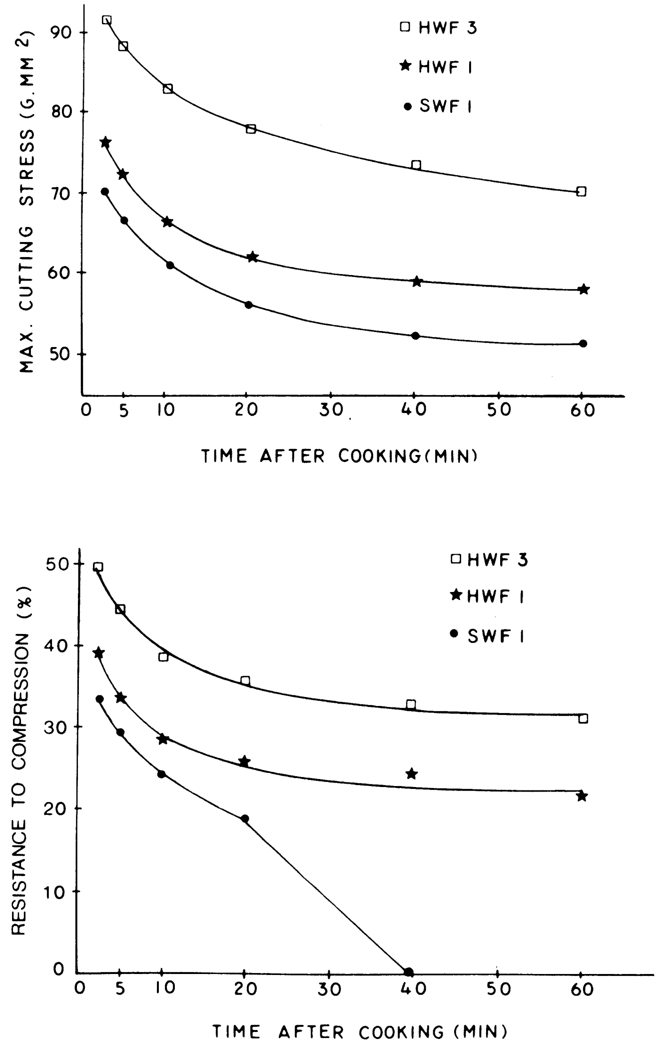

Fig. 6. Effect of standing time (25°C) on the maximum cutting stress and resistance to compression of cooked noodles.

Noodle Thickness vs Maximum Cutting Stress and Resistance to Compression

The thickness of cooked noodles made from the same flour could be reproduced with a coefficient of variation of less than 3.0%. Noodles made from different flours under identical processing conditions, however, often had different cross-sectional dimensions because of differences in elasticity and flow of dough. Cooking and cooling techniques also affected noodle thickness and had to be controlled carefully. In the case of the five noodle samples made in our laboratory under the same conditions, the thickness of the dry and cooked noodles varied from 1.45 to 1.80 mm and from 2.25 to 2.85 mm, respectively (Table VII). Thus, the effect of variable thickness on the maximum cutting stress and resistance to compression of noodles were examined.

Twenty samples of noodles of varying thickness were cooked at their optimum times, which varied between 4 and 23 min. The maximum cutting stress and resistance to compression were plotted against noodle thickness (Fig. 5). The maximum cutting stress and the resistance to compression increased linearly with increased thickness in the range of 1.5 to 3.0 mm. Based on the data in Fig. 5, the maximum cutting stress for all the noodles increased at a rate of 7.0 ± 0.35 g/mm^2 per millimeter of additional noodle thickness, and the resistance to compression increased at a rate of 6.5 ± 0.5% per millimeter.

Effect of Time After Cooking

Voisey et al (1978) showed that the texture of cooked spaghetti varied with time of standing after cooking. Cooked noodles would be expected to behave in the same way. Figure 6 shows the effect of standing time after cooking on the maximum cutting stress and the resistance to compression corrected to a constant thickness of 2.4 mm for the cooked noodles. The maximum cutting stress and resistance to compression changed sharply between zero and 10 min of standing time after cooking. After approximately 20 min of standing time, however, the rate of change decreased and began to level off (Fig. 6).

Noodles are normally eaten as soon as possible after cooking, so a comparison of noodle texture would best be done immediately after cooking. Immediately after cooking, however, the properties of cooked noodles are changing most rapidly (Fig. 6), so we decided to test noodle texture 10 min after cooking. With accurate timing, the maximum cutting stress and resistance to compression values were reproducible with coefficients of variation of less than 5% (Table II).

Effect of Cooking

Tolerance to overcooking is important to the quality of noodles and pasta. Three noodle samples were overcooked 0–12 min at 3-min intervals past their optimum cooking times. After cooling and allowing the cooked noodles to stand 10 min at 25°C, the maximum cutting stress and resistance to compression were measured and corrected to a constant thickness of 2.4 mm. Figure 7 shows the maximum cutting stress and the resistance to compression (except for sample SWF 1) decreased linearly with increased overcooking. Obviously, the weakening of the noodle caused by overcooking was readily detectable by the two instrumental variables.

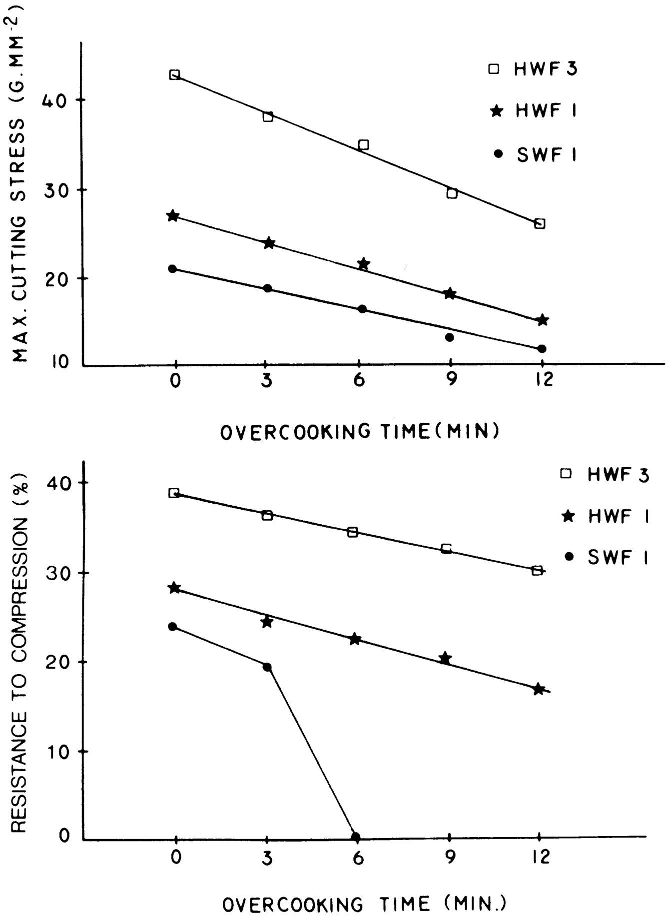

Fig. 7. Effect of overcooking at 98 ± 0.5°C on maximum cutting stress and resistance to compression measured 10 min after cooking.

CONCLUSIONS

The maximum cutting stress and the resistance to compression of cooked noodles measured on the Instron Universal Testing Instrument are reliable and convenient measures of the texture of cooked noodles. These instrumental variables correlated well with sensory evaluation of firmness and chewiness of noodles.

ACKNOWLEDGMENT

The authors thank the Kansas Wheat Commission for financial support.

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[Received December 13, 1982. Accepted June 17, 1983]