Grain Research Laboratory Compression Tester: Instrumental Measurement of Cooked Spaghetti Stickiness[1,2]

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ABSTRACT

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The Grain Research Laboratory compression tester, designed for assessment of bread crumb texture, was modified to permit measurement of cooked spaghetti surface stickiness. The basic principle of the test procedure is to compress cooked spaghetti strands under a plunger and, upon lifting the plunger, measure the force of adhesion of the spaghetti to the plunger. Sample sizes as small as 6 g of spaghetti can be tested. Samples tested to date show a range in stickiness from about $400N/m^2$ to $900N/m^2$. Standard deviation of the test is about $40N/m^2$. Test results seemed to be in good agreement with subjective assessment of cooked spaghetti stickiness by an untrained taste panel. Preliminary investigations showed that cooking water quality and spaghetti drying procedure have a large influence on stickiness of cooked spaghetti. Spaghetti stickiness was also related to cooking time and elapsed time after cooking. Protein content did not appear to be strongly related to spaghetti stickiness.

The ultimate test of acceptability of a durum wheat cultivar is spaghetti cooking quality. Cooked spaghetti must be firm, resilient, and nonsticky for maximum consumer acceptance. Spaghetti cooking quality can be estimated by taste panels (Menger 1979). Unfortunately, it is impractical to use taste panels to test large numbers of samples. In a durum wheat breeding program, in which sample size is limited and the number of samples to be screened is very large, an instrumental method is needed for assessing spaghetti cooking quality.

Many instrumental methods have been reported that successfully estimate cooked spaghetti firmness, resilience, and tensile strength (Abecassis et al 1974; Binnington et al 1939; Feillet et al 1977; Holliger 1963; Matsuo and Irvine 1969, 1971; Voisey and Larmond 1973; Voisey et al 1978a; Walsh 1971). Aside from the exploratory work of Voisey et al (1978b) on the Instron universal tester, we are not aware of any successful attempts to measure cooked spaghetti stickiness instrumentally. D'Egidio and co-workers (1976, 1978, 1981, 1982) reported success in relating sensory evaluation of spaghetti stickiness to the amount of surface material that can be washed from drained cooked spaghetti. However, the techniques of both Voisey et al (1978b) and D'Egidio and co-workers (1976, 1978, 1981, 1982) require at least 100 g of spaghetti, rendering them impractical for a plant breeding program.

Kilborn et al (1982) developed an instrument, the Grain Research Laboratory (GRL) compression tester, to test for bread crumb properties. We thought that, with a few modifications, the instrument could be used to assess surface stickiness of relatively small samples of cooked spaghetti. This article describes the development of the test method adopted for routine assessment of cooked spaghetti stickiness, and presents the results of some preliminary investigations into factors associated with cooked spaghetti stickiness.

MATERIALS AND METHODS

Sample Preparation

Samples of sound Canadian amber durum wheat that were graded No. 2 Canada Western or better were milled into semolina (70% extraction) by the Allis-Chalmers laboratory mill method of Matsuo and Dexter (1980). Semolina protein was determined by the Kjeldahl procedure as modified by Williams (1973), and gluten strength was estimated on ground whole grain by the sodium dodecyl sulfate (SDS)-sedimentation test of Axford et al (1979).

Spaghetti was processed in a DeMaco S-25 laboratory-scale continuous-extrusion press (De Francisci Machine Corp., Brooklyn, NY) using previously described conditions (Matsuo et al 1978). Spaghetti was dried by a conventional low-temperature drying cycle (39°C for 28 hr). Where quantity permitted, a portion of the spaghetti was also dried by a high-temperature drying cycle that featured a 1-hr conventional temperature predrier followed by 12 hr at 72°C. Details of both drying cycles were published previously (Dexter et al 1981).

Instrumentation

The GRL compression tester, originally designed for assessing bread crumb physical characteristics, was described in detail elsewhere (Kilborn et al 1982). In adapting the apparatus to test for cooked spaghetti stickiness, the general concept employed by Voisey et al (1978b) was adopted; the cooked spaghetti was compressed under a plunger and, upon lifting the plunger, the force of adhesion of the spaghetti to the plunger was measured.

The plunger, attached to a force transducer, is moved vertically by a motor-driven cam. The cam provided a change in radius between the cam shaft and cam follower of 0.123 mm per degree of rotation. The motor speed was adjustable to produce a range of linear plunger speeds at both the compression and the stickiness stages of testing. Forces generated during compression of the cooked spaghetti and upon lifting the plunger were traced on a recorder. The instrument was programmed electronically to impart identical compression force during successive tests by using a comparator in conjunction with a digital panel meter readout of force.

Development of Instrumental Test Procedure

Ten grams of spaghetti was broken into 5-cm long strands and cooked to the desired cooking time. Spaghetti was drained for 1 min over a U.S. #10 sieve, and strands were laid side by side on a tray. The cooked spaghetti was covered during the interval between loading onto the tray and testing to minimize day-to-day variations caused by fluctuations in laboratory relative humidity. About 3 min before testing, an aluminum cover plate was placed over the spaghetti strands, the sample was inverted, and excess water was removed with tissue paper. The cover was placed on the tester platform, and the sample was positioned directly under the plunger.

Initial attempts to measure stickiness with the round plunger designed for bread crumb testing were not reproducible because the spaghetti strands tended to lift and shift when the plunger was raised. Therefore, a polished aluminum plunger and sample retainer were constructed that largely eliminated this problem. The plunger was rectangular (40 × 19 mm contact surface), and fastened to an adapter ring that slipped over and fastened to the bread plunger (Fig. 1). An aluminum plate (100 × 100 × 6 mm) with an

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opening (43 × 22 mm) for plunger-to-sample access was used as a sample retainer. The weight of the plate (165 g) was sufficient to prevent changes in the spaghetti strand alignment.

Previously, Voisey et al (1978b) found that stickiness readings were influenced by plunger speed. Therefore, in our test procedure, plunger speed was carefully maintained at 4 mm/min. In agreement with Voisey et al (1978b), we found that stickiness values were independent of compression force over a fairly wide range (results not shown). Below about 2,500N/m^2, stickiness values decreased, possibly because of uneven surface contact between the plunger and the cooked spaghetti, whereas above 12,500N/m^2, stickiness values increased, presumably because of deformation of the cooked spaghetti. For routine testing, an intermediate compression force of about 5,200 N/m^2 was maintained.

Some typical recorder tracings are shown in Fig. 2. Just before testing, the recorder system was zeroed on the expanded scale used for measuring stickiness, and the scale was then reduced to permit monitoring of the compression force. The comparator was set to the desired compression force (normally 400 g, equivalent to 5,200N/m^2). The motor was switched on, and the plunger moved down onto the spaghetti surface. When the maximum compression force was reached, the motor was stopped electronically and manually reversed. As the recorder tracing declined because of decreasing compression force, the recorder scale was expanded to permit accurate measurement of stickiness. As the plunger lifted from the surface of the cooked spaghetti, a depression was recorded because the cooked spaghetti adhered to the plunger surface. The motor was continued in reverse until zero was reached. Stickiness was defined as the maximum depression recorded during lifting of the plunger. The part of the declining curve that appears "busy" around 2,000N/m^2 on the compression scale is the result of the multiswitching used to expand the scale and is of no significance in sample assessment.

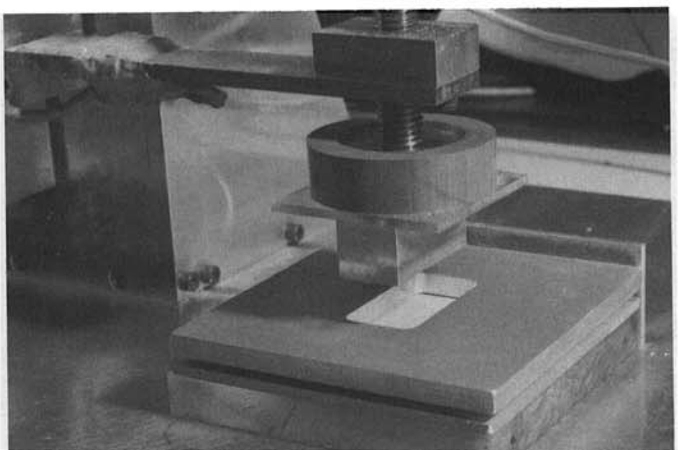

Fig. 1. Modified plunger surface and sample holder for instrumental assessment of spaghetti stickiness.

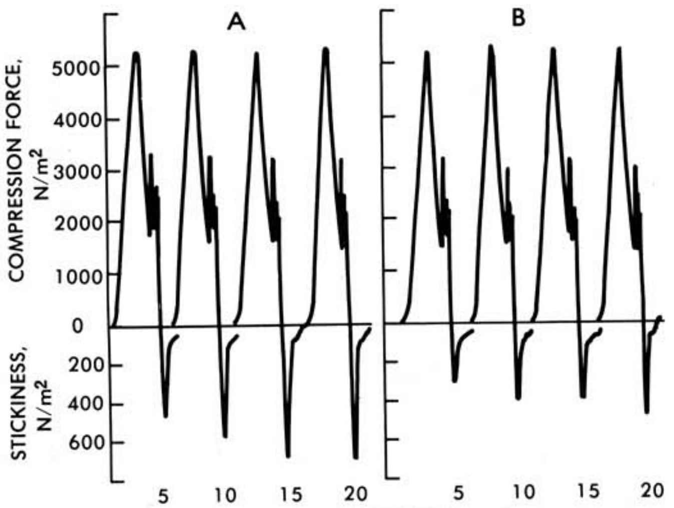

Fig. 2. Typical recorder tracings illustrating the effect of elapsed time following cooking on the instrumental assessment of cooked spaghetti stickiness for a sticky **(A)** and a nonsticky laboratory sample **(B)**.

Taste Panel

To judge spaghetti stickiness, an untrained taste panel of six persons was selected from our laboratory staff. Three samples that had been determined instrumentally to represent a range of stickiness were chosen for the test. The three samples were cooked simultaneously to optimum time, drained, and presented to one of the panelists. One sample was identified as a control and given an arbitrary score of 3. The panelist was requested to score the other two samples on a scale of 1 to 5 according to the extent that the strands clung together and by touch. A score of 1 was defined as much less sticky than the control, and a score of 5 was defined as much more sticky than the control. The three samples were cooked separately for each of the panelists, who scored the samples completely independently of each other.

Cooking Water

Spaghetti samples were assessed for stickiness in laboratory tap water and deionized water. Large quantities of tap water were collected before experimentation to ensure that any differences observed were not masked by variations in tap water quality from day to day. The deionized water was obtained by distillation, deionized by reverse osmosis, and passed through a series of columns (Millipore Corp., Belford, MA) including a prefiltration, charcoal, and ion-exchange column, and a final filtration.

RESULTS AND DISCUSSION

Precision and Relationship to Taste Panel

To establish precision of the instrumental cooked spaghetti stickiness test, a control laboratory spaghetti was cooked 20 times in both tap water and deionized water. Precision was very similar for both types of cooking water, the coefficient of variation being 6.50% in tap water and 6.30% in deionized water.

The three samples used for the taste panel tests consisted of the control, which yielded an instrumental stickiness value of 570N/m^2 in tap water, and two other samples, which yielded stickiness values of 470N/m^2 and 760N/m^2, respectively. All six panelists judged the sample with the highest instrumental stickiness value to be much stickier than the control. The other sample was judged to be slightly less sticky than the control by three panelists, the same as the control by two other panelists, and slightly stickier by the other panelist. Compared to the arbitrary score of 3 established for the control, the panelists gave mean scores of 2.8 and 4.4 for the other two samples. Although not conclusive, these limited results gave us confidence that the instrumental procedure was related to cooked spaghetti stickiness as would be perceived by the consumer.

Factors Influencing Stickiness

Cooked spaghetti samples became progressively stickier as the length of time between draining and testing was increased (Fig. 2). A similar result was reported by Voisey et al (1978b). This increase in stickiness with time can be explained on the basis of increased surface dryness of the cooked spaghetti because of the combined effect of evaporation of surface water and absorption into the spaghetti. As the surface dries, it becomes increasingly tacky because of loss of lubrication from free surface water.

Samples generally ranked in the same order of stickiness over a wide range of times following drainage. Some typical results for a sticky and a nonsticky laboratory sample are shown in Fig. 2A and B, respectively. As elapsed time following cooking increased beyond 10 min, the precision of the stickiness test tended to decrease (results not shown). Therefore, as a routine procedure, samples were tested for stickiness 10 min after cooking. This gave the operator ample time to prepare for the test while maintaining a sufficiently high degree of precision.

We anticipated that cooking time might also play an important role in determining stickiness of cooked spaghetti, as increasing cooking time results in reduced cooked spaghetti firmness and resilience (Dexter and Matsuo 1977, Grzybowski and Donnelly 1979). According to Menger (1980), taste panel results showed that cooked pasta tends to become sticky as cooking time is increased. In contrast, we found that all samples tested instrumentally exhibited a significant ($P \leq 0.01$) tendency to decreased stickiness with increasing cooking time. This is illustrated by Fig. 3, which shows typical results for two laboratory samples varying widely in stickiness.

Although spaghetti samples tested in the current study became less sticky as cooking time increased, they exhibited a much greater tendency to reduced firmness, loss of resilience, and general deterioration of surface characteristics, resulting in much reduced overall textural quality. These trends could conceivably mask any improvement in cooked spaghetti stickiness during taste panel assessment.

As shown in Fig. 3, samples of varying stickiness tended to exhibit greater relative differences at short cooking times, but tended to rank in the same order over a wide range of cooking times. As a routine quality assessment procedure, we cooked to optimum cooking time, defined as the time required for the white core in the strand to disappear (Dexter and Matsuo 1977). Optimum cooking time, which varies according to strand diameter, was about 12 min for our laboratory-processed samples.

Cooked spaghetti stickiness is related to the proportion of surface material that can be rinsed from the cooked spaghetti following drainage (D'Egidio et al 1976, 1978, 1981, 1982; Menger 1980) and is not necessarily related to total solids lost to cooking water. Although solids lost to cooking water increase with increasing cooking time (Dexter and Matsuo 1979, Grzybowski and Donnelly 1979), surface material may not necessarily follow

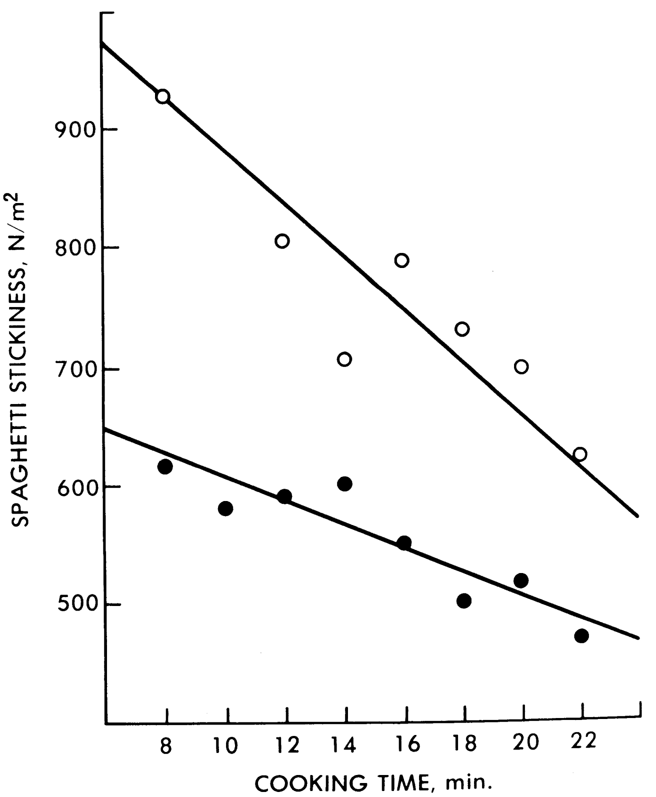

Fig. 3. Typical results illustrating the effect of cooking time on the instrumental assessment of cooked spaghetti stickiness for a sticky laboratory sample (o) and a nonsticky laboratory sample (•).

the same trend. Surface material might decrease with cooking time because of surface material leaching into the cooking water at a greater rate than it is regenerated. Alternatively, the observed decrease in stickiness following prolonged cooking might be related to compositional changes in the surface material. Both possibilities are under investigation.

Cooked spaghetti firmness and resilience are strongly correlated to protein content (Dexter and Matsuo 1977, Grzybowski and Donnelly 1979). However, as shown in Table I, although stickiness tended to decrease slightly as protein content increased, protein content appeared to play a limited role in determining spaghetti stickiness compared to both cooking water quality and spaghetti drying conditions. The relatively narrow range of gluten strengths estimated for the samples by the SDS-sedimentation test would not be expected to be a significant factor in determining cooked spaghetti firmness or resilience (Dexter et al 1980), so it probably would not have much of an effect on relative stickiness values.

The effect of cooking water was very striking, particularly in the case of low-temperature (LT) dried spaghetti. Whereas LT samples A, B, and C were undesirably sticky in tap water, all were satisfactory when cooked in deionized water. The range of stickiness observed when the LT samples were cooked in deionized water was also greatly reduced. The tendency towards decreased stickiness when spaghetti is cooked in deionized water was reported previously, first by Alary et al (1979) and later by Menger (1980) and D'Egidio et al (1981), and was related to differences in pH and hardness, particularly the presence of calcium and magnesium carbonate. The ability of our instrumental procedure to detect the same relationship established by other workers who used taste panel results gives further strong evidence that the instrumental test results give a meaningful estimate of cooked spaghetti stickiness.

When cooked in tap water, the high-temperature (HT) dried spaghetti for samples A, B, and C were much less sticky than the corresponding LT spaghetti (Table I). In sample D, where the LT spaghetti was not very sticky, the HT spaghetti was equally as sticky as the LT spaghetti. The decrease in stickiness of cooked spaghetti by HT drying is in agreement with a report by Manser (1981), providing further confirmation that our instrumental stickiness test gives meaningful values.

If HT drying is to improve spaghetti quality, the onset of HT should be delayed until the spaghetti moisture has been reduced to below 20% by a conventional predrier (Dexter et al 1981, Manser 1981). By increasing the duration of HT and by increasing temperature to the maximum practical limit, the magnitude of improvement in cooked spaghetti properties can be improved (Manser 1981). In the current study, our maximum temperature was only 72°C, as opposed to some successful commercial drying cycles that use temperatures of 80°C or more. If a higher temperature had been used in the current study, an even greater effect on spaghetti stickiness might have been observed.

Stickiness values for LT spaghetti were much more sensitive to cooking water quality than for HT spaghetti. The apparent greater resistance of HT spaghetti to cooking water quality could be very important commercially. Although the pasta manufacturer has no control over the hardness of cooking water used by the consumer, by processing under HT conditions the manufacturer could

TABLE I
Effect of Protein, Cooking Water, and Spaghetti Drying Temperature on Stickiness of Cooked Spaghetti[a]

Semolina	Protein (%)	SDS-Sedimentation Volume (ml)	Spaghetti Stickiness, N/m² Tap Water LT[b]	HT[b]	Deionized Water LT[b]	HT[b]
A	12.3	43.1	710	630	530	510
B	12.9	39.4	710	550	520	490
C	14.3	47.2	730	570	560	450
D	15.3	38.7	570	570	490	470

[a] All samples cooked to optimum time (12 min). Stickiness values are means of triplicate analyses.
[b] LT = Low temperature, HT = high temperature.

eliminate many consumer complaints related to poor cooking water quality.

GENERAL DISCUSSION

We chose not to rinse the spaghetti before testing for stickiness. As noted by Menger (1980) and confirmed by us during preliminary experiments (results not shown), rinsing greatly overcomes stickiness. Also, as stated by Voisey et al (1978b), where spaghetti is consumed with a sauce, as is common practice in North America, stickiness would be greatly reduced.

We chose to test our samples unrinsed because it maximized our range of values. However, of equal importance was the consideration that in the major European pasta markets, whose consumption of Canadian durum wheat is much greater than Canadian domestic consumption, pasta is usually eaten unrinsed.

Although 10 g of spaghetti was used in routine testing, sample size can be reduced to about 6 g when quantity is a limiting factor. One operator can easily perform 15 analyses per day, making the test sufficiently rapid for use in advanced stages of the Canadian durum wheat breeding program.

In addition to those factors considered in this preliminary study, spaghetti stickiness could be dependent on a large number of other factors as well. These may include gluten strength, sprout damage, semolina granulation, extrusion conditions, and addition of nondurum wheat raw materials. Research into the effect of these and other factors associated with cooked spaghetti stickiness is in progress.

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