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Spaghetti Tenderness Testing Apparatus [1]

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ABSTRACT

An apparatus for measuring the tenderness of cooked spaghetti is described. To simulate the "bite test", a continuously increasing force is applied to a cutting edge. The rate of movement is measured with a linear variable differential transformer. The rate of cutting is recorded and the curves, which are reproducible, are interpreted in terms of a tenderness index. The index is the slope at the midpoint of the curve. Values ranging from 0.029 to 0.060 mm./sec. were obtained. Low values correspond to firm spaghetti and high values to soft spaghetti. For the range of samples studied, results indicate that the apparatus is sufficiently sensitive to differentiate spaghetti made from various varieties and types of wheat.

There is need for a reliable parameter for characterizing the tenderness of cooked pasta products to help elucidate the factors associated with cooking quality. At present there is no satisfactory means of measuring tenderness other than the bite test. This is unsatisfactory because of the difficulty in assigning an index and also because the test is subject to individual bias.

The apparatus developed by Binnington *et al.* (1), although given as the official method in Cereal Laboratory Methods (2), has never been widely used. An apparatus for measuring the torsional strength of macaroni was described by Karacsonyi and Borsos (3). The authors claim that "the measurement of torsional strength gives an accurate index of the quality of macaroni samples." The breaking strength of the dry product is not necessarily related to cooking quality. Holliger's apparatus (4) measures the breaking strength of uncooked spaghetti as well as the tensile strength of cooked spaghetti, but no attempt has been made to interpret the curves in terms of a tenderness index.

An attempt has been made by us, therefore, to design an instrument which would simulate the bite test and which would possess sufficient sensitivity to differentiate spaghetti made from different varieties of wheat on the basis of the tenderness of the cooked product.

The Apparatus

In the design, several factors were taken into consideration. It seemed desirable to shape the cutting edge like a tooth to simulate the "bite test." The force required to cut the strand of spaghetti should be measurable graphically, e.g., by a recorder, together with the rate of movement of the cutting edge. The rate of movement of the cutting edge as it moves through the spaghetti should then provide a measure of the firmness of the cooked product. The time required for the test should be short to minimize loss of water from the sample during the test.

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Basically, the apparatus was designed with a cutting edge to which an increasing force could be applied. As the strand of cooked spaghetti is cut by means of the applied force, the movement of the cutting edge is measured and recorded.

To measure the movement of the cutting edge, a linear variable differential transformer (LVDT) is used. The LVDT obtained from Shaevitz Engineering is schematically represented in Fig. 1. The cutting edge is attached to the core of the transformer with an aluminum rod. The output voltage is rectified with a silicon diode and adjusted with a 2,000-microhm multipot precision potentiometer. A Heathkit Audio Generator, Model AG8, supplies the primary input voltage.

The apparatus utilizes the beam and the movable carriage of the Buhler Bending Stress Tester to apply a continuously increasing force to the cutting edge as shown in Fig. 1. The LVDT is attached firmly to the base. The connecting rod from the

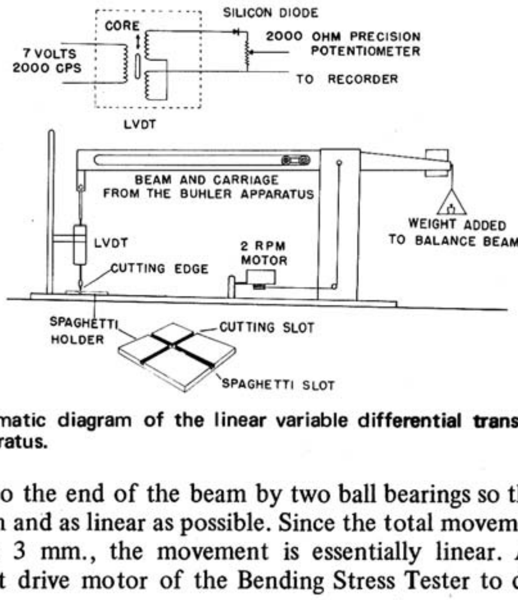


Fig. 1. A, schematic diagram of the linear variable differential transformer. B, essential features of the apparatus.

core is attached to the end of the beam by two ball bearings so that the motion of the core is smooth and as linear as possible. Since the total movement of the cutting edge is less than 3 mm., the movement is essentially linear. A 3-r.p.m. motor replaces the chart drive motor of the Bending Stress Tester to drive the movable carriage.

Weights are added to the end of the beam (as indicated in the diagram) so that the cutting edge is balanced level with the top of the spaghetti holder. The motor which drives the movable carriage is connected to the recorder switch. The output voltage from the LVDT is adjusted to give a full-scale deflection on the recorder for a movement of the cutting edge equivalent to the thickness of cooked spaghetti.

Figure 2 shows the increase of load on the cutting edge with time. The recorder chart speed is 6 in./min.; the load or force at any point on the curve is thus easily calculated.

MATERIALS AND METHODS

Both commercially produced and laboratory-processed spaghetti samples were tested. Two of the commercial samples were made in Switzerland, one in Italy, and six in Canada.

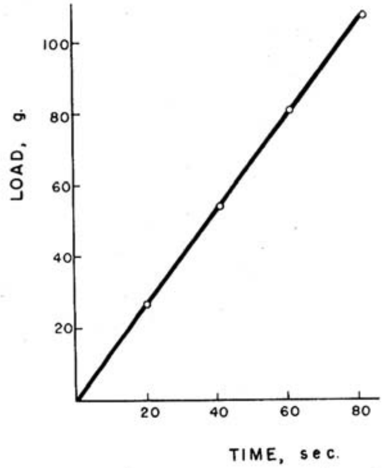
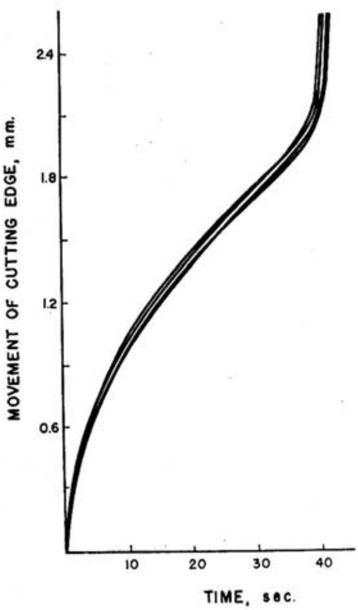


Fig. 2. Calibration curve of load on the cutting edge *vs.* time.

Laboratory samples were processed by the micro-macaroni method (5) using semolina milled from various grades and varieties of durum wheat.

For cooking the samples, 10 g. of spaghetti was placed in 100 ml. of rapidly boiling tap water. The cooking time is taken as the time required for the white core in the strand to disappear. A strand is removed from the cooking water and cut with a sharp edge at intervals. The time for the white core to disappear varies from



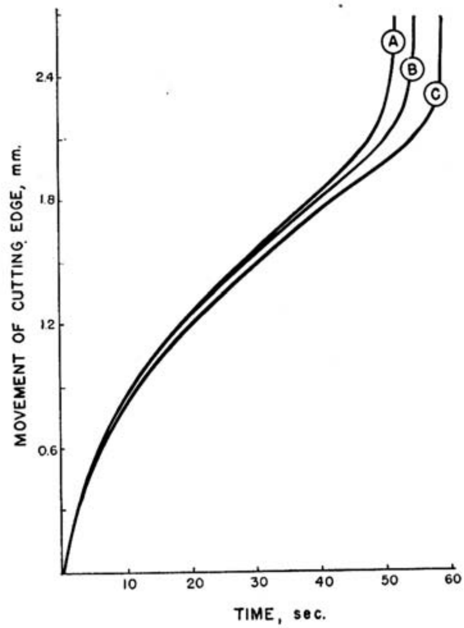


Fig. 3. Reproducibility of curves.
Fig. 4. Effect of spaghetti diameter on cutting time. A, 1.78 mm.; B, 1.85 mm.; C, 1.98 mm.

12 to 15 min. Duplicate determinations were made for all samples. Cutting tests were carried out immediately after cooking.

The diameter of each strand of uncooked spaghetti was determined with a drill and wire gage. Commercially produced samples varied from 1.55 to 2.13 mm., whereas samples made in our Laboratory varied from 1.70 to 1.98 mm.

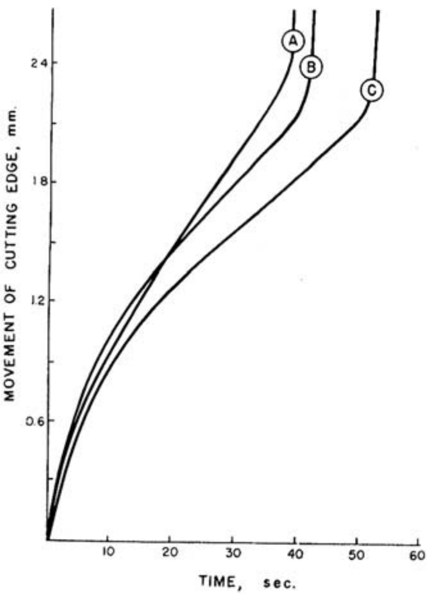
RESULTS

The reproducibility of the curves is shown in Fig. 3. The time required for the sample to be completely cut varied from 39 to 42 sec. in quadruplicate tests. The sample was commercially produced and had an uncooked diameter of 1.78 mm. Thus, for samples of uniform diameter, reproducibility of curves is reasonably good. However, poorer reproducibility in terms of cutting time, as in the case of laboratory-processed samples, is not important, since it is the slope of curve, as explained below, that is significant.

Figure 4 shows the effect of the diameter of spaghetti. From a commercial sample, strands were separated into three sizes of diameter, 1.78, 1.85, and 1.98 mm. As would be expected, the time required to cut the strand increases as the diameter increases.

Figures 5 and 6 show curves obtained from commercial and laboratory samples, respectively. Only three of each are shown, to indicate the variations obtainable from different samples.

The addition of salt to the cooking water has been reported to have a significant softening effect on the cooked product (1). The cooking time, however, was 30 min., considerably longer than the time used in the present work. The addition of



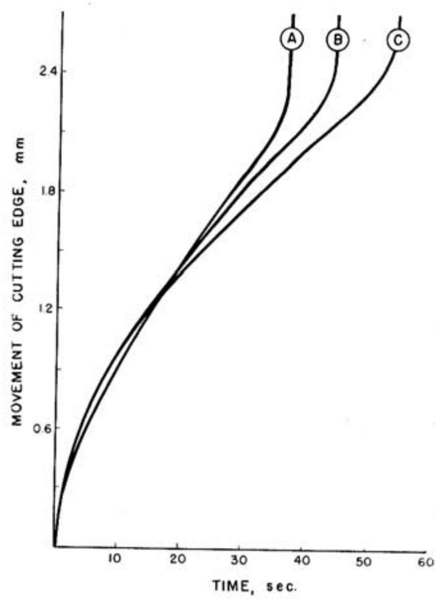


Fig. 5. Curves of commercially produced samples. A, Canadian; B and C, European.
Fig. 6. Curves of laboratory-processed samples. A and B, Canadian; C, foreign.

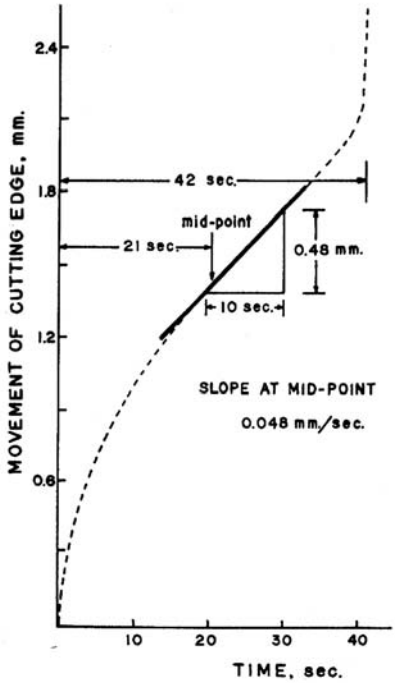


Fig. 7. Calculation of the slope.

0.5% salt to the cooking water had no effect on the tenderness of any of the samples tested.

Derivation of a "Tenderness Index"

The time required for the strand to be cut gives an indication of tenderness: the softer the sample, the shorter the time. Unfortunately, the time is also a function of the spaghetti diameter, as shown in Fig. 4. Even in commercially produced samples there are fluctuations in spaghetti diameter between and within strands. In laboratory-processed samples where extrusion pressure is not constant, the variation in diameter in a single strand is greater. A tenderness index based on cutting time and diameter is unsatisfactory because of variation in diameter.

A better index of tenderness can be derived from the characteristics of the curve. There is a point of inflection on the curve which corresponds to the

TABLE I. TENDERNESS INDEX FOR CURVES OF FIGURES 3, 4, 5, AND 6.

Sample (Fig. No.)	Cutting Time sec.	Tenderness Index slope, mm./sec.	Sample (Fig. No.)	Cutting Time sec.	Tenderness Index slope, mm./sec.
3	42	0.047	5A	40 [± 2]	0.060
	42	.048	B	43	.046
	40	.047	C	52	.029
	39	.047	6A	35 [± 3]	.059
4A	52 [± 2]	.029 [± 0.001]	B	43	.043
B	54	.030	C	51	0.037
C	59	0.029			

maximum resistance during cutting. The slope at this point is a minimum and is readily calculated by drawing a tangent at the midpoint of the curve. The midpoint of the curve is taken as one-half of the cutting time. Figure 7 shows how the slope is calculated. A tangent is drawn by visual inspection, and movement of the cutting edge is measured for a time interval of 10 sec. The slope is defined as the tenderness index and represents a rate with units of mm./sec.

High values correspond to soft cooked products. Tenderness indices derived from the curves of Figs. 3 to 6 are given in Table I. The values for curves in Fig. 4 clearly indicate that the slope is independent of the cutting time. In Fig. 5, although the cutting times for samples A and B are similar, the slopes are quite different. Thus, differences in the slope, i.e., differences in the tenderness of cooked spaghetti, are readily detectable. The error in the slope between and within days was ±0.001 units.

For the range of samples studied, the apparatus is sufficiently sensitive to differentiate spaghetti made from different durum varieties. Studies with this apparatus, to determine the relation of various factors such as protein content, type of gluten, and the amount of water uptake by spaghetti during cooking, to tenderness, are continuing.

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