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DEVELOPMENT AND APPLICATION OF ARMOUR TENDEROMETER FOR MEASURING TENDERNESS OF BEEF CARCASSES

LEO J. HANSEN

Food Research Division, Armour and Co.,
Oak Brook, Ill. U.S.A.

INTRODUCTION

To most consumers, tenderness of meat is its most important quality attribute. The meat industry has endeavored to respond and supply meat of improved tenderness. Among these efforts have been breeding programs, where selection for tenderness has been a criterion, and management and feeding practices where more finish is placed on cattle in an effort to improve eating quality.

In recent years research to develop a better understanding of tenderness has been very active in many laboratories. The subject is complex and several factors appear to be involved.

The purpose of the work reported here was, not to get involved in studying the underlying factors responsible for relative tenderness or toughness, but through an empirical approach, develop a simple rapid non-destructive test for tenderness. Ideally this test should work on raw meat and be applicable at the carcass level. It could then be used in a slaughtering plant cooler to select beef for a guaranteed naturally tender marketing program.

EXPERIMENTAL METHODS

The rationale adopted at the onset of this work was to concentrate on studying the possibility of finding a practical physical test. It was hoped that some measure taken on the raw meat would predict the tenderness found after the meat was cooked. However, as pointed out in the review by Szczesniak (1965) attempts to relate Warner-Bratzler shears on raw meat to those obtained after cooking have resulted in low or in non-significant correlation coefficients.

The first step in this research, therefore, was to investigate the possibility of a number of approaches for making a physical test on raw meat to predict tenderness after cooking. An Instron Universal Testing Machine was used. This permitted the study of a number of different test probes and also different test approaches. Two groups of probes were evaluated. The first group of probes and devices is shown in Figures 1 and 2. These were intended to be used on small meat samples, 1"x1"x1/2" in size. The fibers ran parallel to a one-inch side. These small meat samples were sawed from frozen muscles, allowed to thaw at 35°-40°F and tested while at this temperature. The large blunt penetration probe shown at the top in Figure 1 was driven into the 1/2" thick meat samples to a clearance of 0.015" from the flat steel base on which the sample rested. The flat surfaced compression probe, shown second from the top in Figure 1, was run down into the sample to a clearance of 0.065". Shearing of the 1"x1"x1/2" samples was done with the inverted V blade shown third from the top in Figure 1. The angle of the V and the cutting edge were similar to that of the blade in the Warner-Bratzler shear machine. A device attempting to get a composite measure of penetration compression and shear is shown in Figure 2. The 1"x1"x1/2" samples were placed straddling the bottom of the trough and the blunt wedge shaped member came down across the fibers to a clearance of 0.050" from the bottom.

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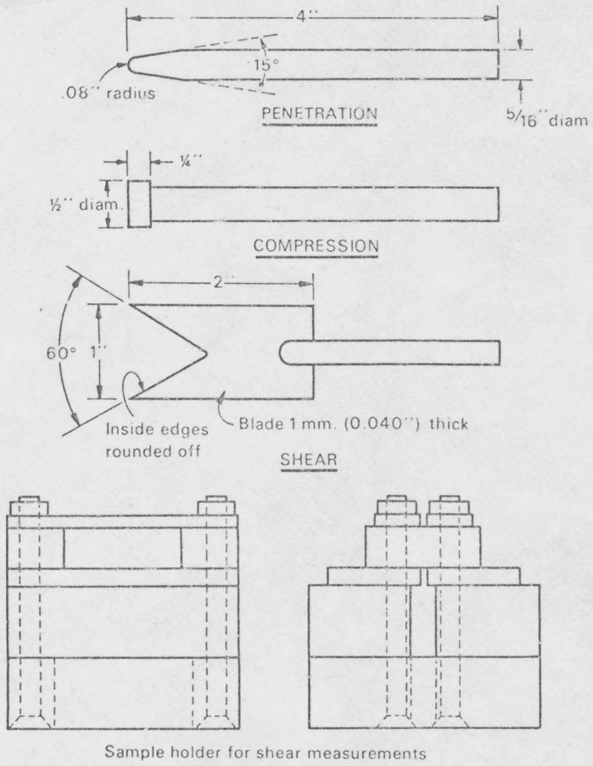

Figure 1. Probes used in Instron Universal Testing Machine for making measurements on small raw meat samples.

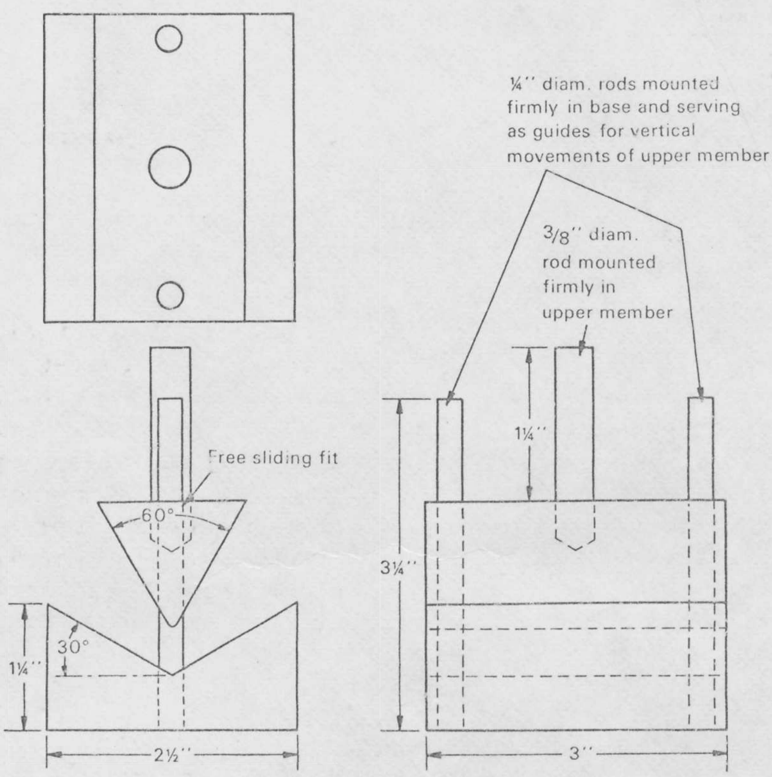

Figure 2. "Wedge Block" device used in Instron Universal Testing Machine on small raw meat samples.

In testing of all the above probes, the Instron Machine was set to drive the probes at a speed of 10 inches per minute. To insure that there was a spread in the range of tenderness to toughness in the samples tested, five different muscles from a total of nine carcasses were used.

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The second group of probes are shown in Figure 3. These were intended for penetration into a larger muscle mass. The muscle pieces used with these probes were 3 or more inches thick. During testing they were retained in a clamp type holder. This prevented deformation and lateral pushing out of the sample during penetration. Holding in this manner was found necessary in order to get reproducible measurements. The firmness ball was pushed into the sample for one inch and the other probes were run in for a distance of two inches from the surface.

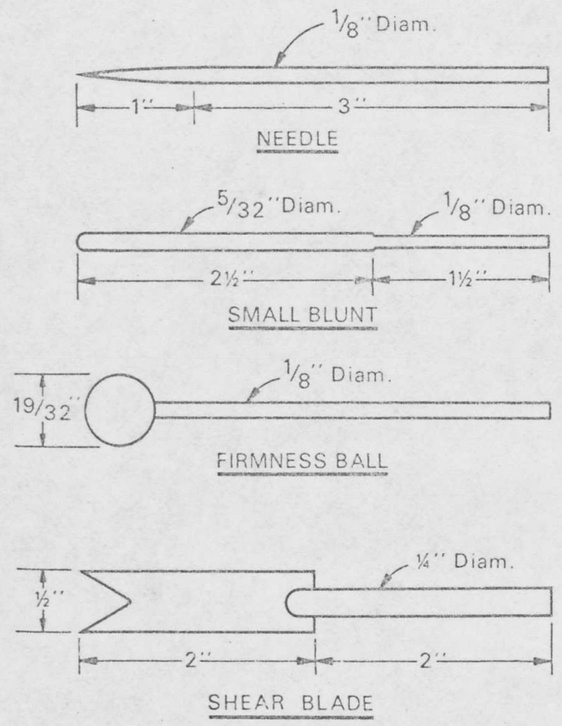

Figure 3. Probes used in Instron Universal Testing Machine for making penetration resistance measurements into larger muscle samples.

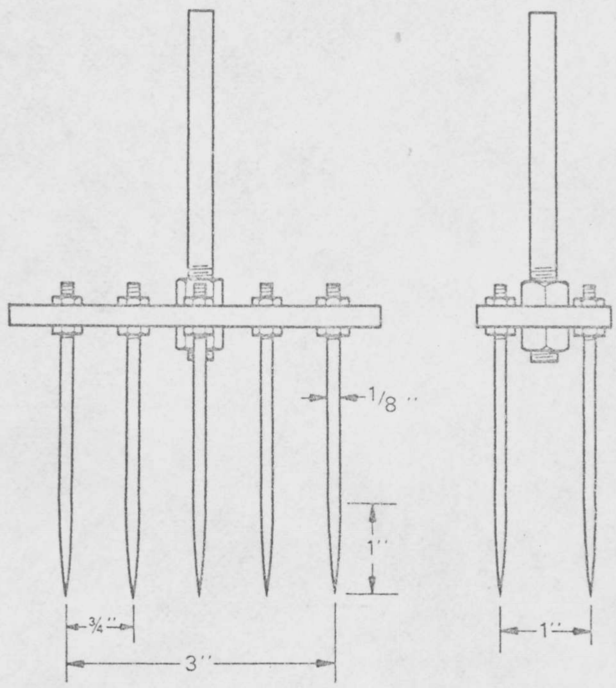

Figure 4. Multiple needle probe.

Results from testing this second group of probes indicated that the 1/8" diameter needle shaped probe had the most promise. It was therefore incorporated into a ten needle probe where the ten needles were mounted on a plate. There were two rows one inch apart with the needles 3/4" apart in the row. This probe is shown in Figure 4. It was first tested using the Instron Testing Machine to force the probe two inches into muscle samples retained in a holder. Later a similar ten needle probe was mounted on a strain gauge transducer assembly which in turn was connected by a cable to a battery operated electronic read-out instrument. This Tenderometer instrument was used on the exposed rib eye surface of beef carcasses. The probe was pushed in manually.

Warner-Bratzler shear tests were made on cooked samples at a number of stages in the course of this study. The meat samples were first cut into two-inch thick slices. These were roasted in a 350°F oven to 150°F internal. The roasted meat was chilled to about 40°F before cutting out the one-inch cores for shearing.

RESULTS

The first testing of the first group of probes shown in Figure 1 and 2 was to determine the repeatability of individual replicated measurements taken on samples from the same muscle. These results are summarized in Table I. They show that all four probe devices used in the Instron gave less variation among replicates than the Warner-Bratzler shear test. The last two columns of Table I were obtained by using a formula from Snedecor (1946) for calculating required sample size. The formula was $N = \frac{t^2 \quad s^2}{(\bar{x} - m)^2}$. The smaller variation with the probes used in the Instron resulted in smaller sample sizes required to obtain a given level of precision.

Table I. Variability of Readings and Sample Size Requirements. (Semimembranosus)

						Number of Readings Required to get a Mean Value Within Either 10 or 25% of True Population Value	
	n	$\bar{x}$	s	$s_{\bar{x}}$[a]	c.v.	10%	25%
Warner-Bratzler shear on cooked 1 in cores	25	19.4 lbs.	6.3	2.0	32.4%	42	9
Warner-Bratzler shear on raw 1/2 in cores	40	8.4 lbs.	3.0	.95	36.3%	53	10
Instron on 1"x1"x1/2" raw samples -							
Penetration	50	3.9 lbs.	.98	.31	25.4%	28	6
Compression	20	22.2 lbs.	5.6	1.77	25.2%	28	6
Shear	20	15.8 lbs.	5.0	1.58	31.6%	40	9
Wedge Block	20	60.8 lbs.	12.1	3.83	19.8%	17	5

[a]Standard error assuming a sample size of ten.

The next step was to determine how well these physical tests on raw meat samples correlated with tenderness after cooking. The Warner-Bratzler shear on a cooked sample was used as the measure of tenderness after cooking. At least ten shears were obtained and averaged. Ten measurements were made with each probe on raw samples and the results averaged. The correlations obtained working with a diverse population of five muscles (psoas, longissimus dorsi, semimembranosus, semitendinosus, and biceps femoris) from nine carcasses (six U.S. Choice and three U.S. Good) are summarized in Table II. It will be noted that highly significant correlations were found.

Table II. Correlation of Various Physical Tests on Raw Meat with Tenderness after Cooking.

	r	r^2	$s_{y \cdot x}$
Correlation of Warner-Bratzler Shear on Cooked with:			
Warner-Bratzler Shear on Raw	.82**	.67	2.97
Instron Penetration of Raw	.72**	.51	3.60
Instron Compression of Raw	.83**	.68	2.90
Instron Shear of Raw	.83**	.69	2.98
Instron Wedge Block of Raw	.74**	.54	3.48

**$p < .01$ (Population consisted of 45 samples, 5 different muscles from 9 carcasses)

The probes shown in Figure 3 were intended for testing in larger samples. These probes, as well as the large blunt probe shown at the top of Figure 1, were used on three-inch sections from beef short loins. The grades were either U.S. Choice or U.S. Good. Again, the average of ten individual penetrations into a given sample was used to predict tenderness as indicated by Warner-Bratzler shear on the cooked meat. The correlations found in this more restricted population are summarized in Table III. Only the needle gave a highly significant correlation.

Table III. Correlation of Probe Resistance into Raw *Longissimus Dorsi* with Warner-Bratzler Shear after Cooking.

	n	r	$s_{y.x}$
Needle	23	.56**	3.15
Large Blunt	23	.404*	
Small Blunt	13	.002	
Firmness Ball	13	.36	
Shear Blade	13	.38	

*P <.05 **P <.01

Based on this success with the individual needle, the probe with ten needles was made. The first testing of the ten-needle probe was in the Instron on a population consisting of the five muscles mentioned above. Penetration resistance with this probe was compared to Warner-Bratzler shear on the same sample after cooking. The results are summarized in the graph shown in Figure 5. These showed a highly significant correlation.

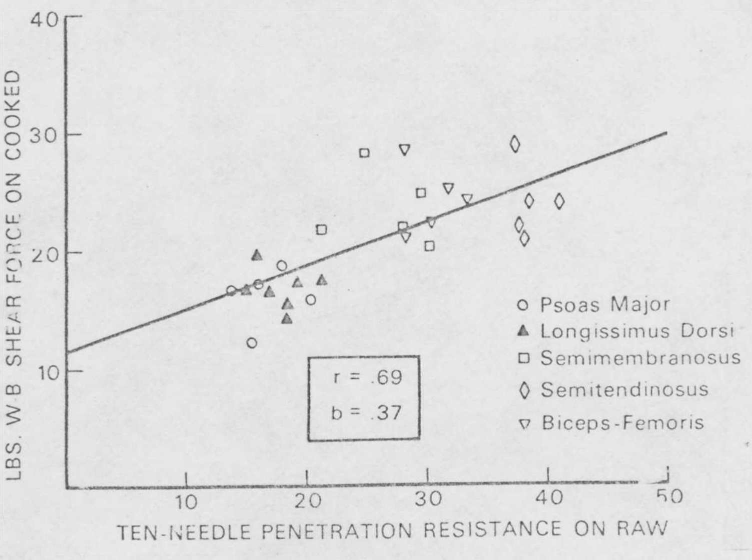

Figure 5. Correlation of penetration resistance, as measured by the use of a ten-needle probe in the Instron, with Warner-Bratzler Shear on the same meat after Cooking.

The final step was to incorporate the ten-needle probe in a portable Tenderometer suitable for making measurements in a plant cooler. These measurements were made in the exposed rib eye on the day after slaughter. The meat temperatures were in the range between 32° and 40°F. Short loins from selected carcasses were evaluated after aging for one week by a skilled tenderness panel. This panel was selected on the basis of individuals' ability to correctly discriminate between differences in tenderness.

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The results indicated that the U.S. grades Good and Choice should be handled as separate populations. Apparently the solidified intramuscular fat added to the penetration resistance reading.

The two graphs relating tenderness panel scores to Tenderometer penetration resistance are shown in Figures 6 and 7. These results show good agreement between the Tenderometer and the skilled panel.

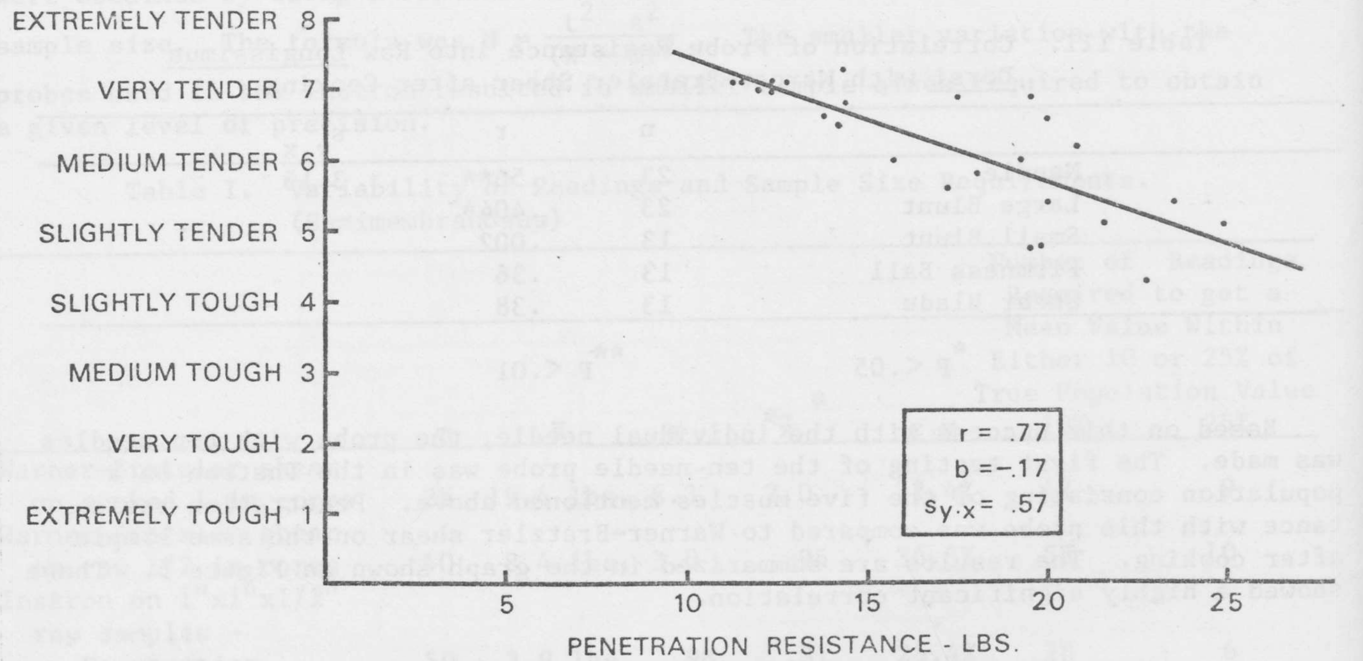

Figure 6. U.S. Choice population - Tenderometer measurement vs. panel tenderness score.

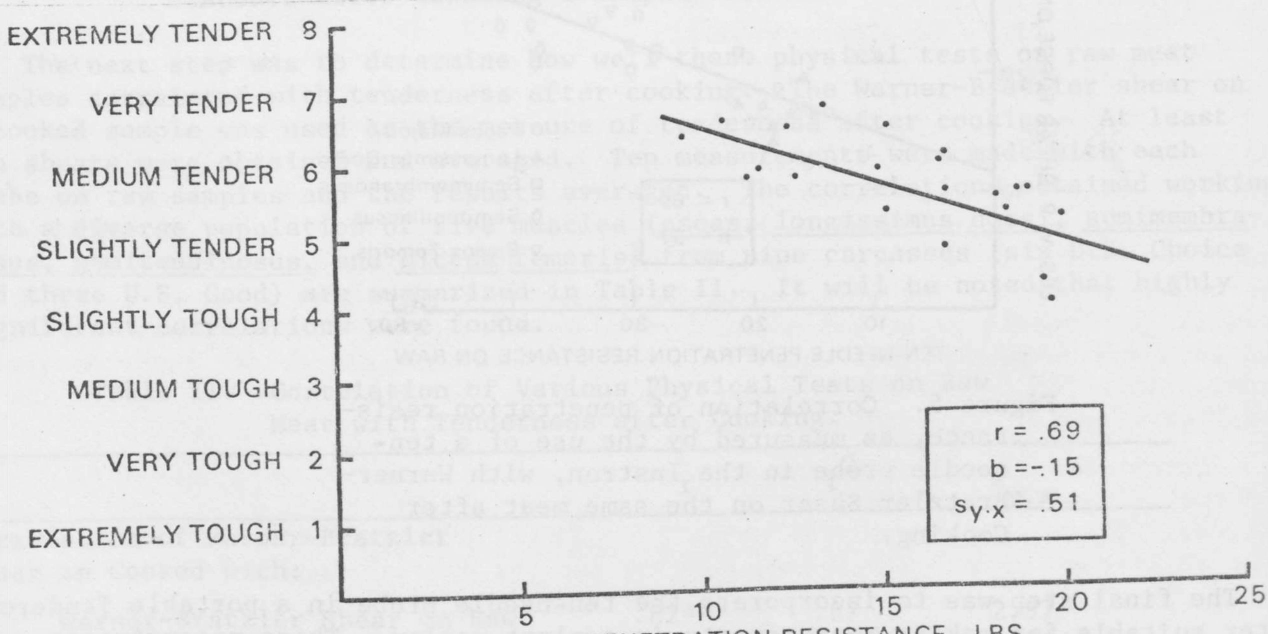

Figure 7. U.S. Good Population - Tenderometer measurement vs. panel tenderness score.

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Warner-Bratzler shear tests were also made on cooked meat samples from the loins. This made possible the comparisons shown in Table IV. The shear values used were obtained by taking six one-inch cores and making three shears per core. Using this number of shears resulted in good agreement with the panel. However, the agreement between Tenderometer and shear was not as good. Apparently both mechanical methods measure part of what makes up the overall impression of tenderness to the judge but they do not necessarily measure the same factors to the same extent.

Table IV. Correlation of Tests for Tenderness

	U.S. Choice	U.S. Good
Tenderometer vs. Panel	.77**	.69**
Tenderometer vs. Warner-Bratzler Shear	.42*	.30
Warner-Bratzler Shear vs. Panel	.68**	.70**

*P .05 **P .01

DISCUSSION

The aim in this work was to carry out a systematic study of some mechanical approaches for measuring tenderness. Careful quantitative analysis was carried out in conjunction with each step.

The results obtained in this development effort demonstrated that it is possible to find a relationship between certain physical tests on raw meat and its tenderness after cooking. In order to demonstrate the relationship between physical test results on raw meat and its tenderness after cooking, two provisions must be met which are beyond the problem of designing a mechanical test device that yields sufficiently accurate predictions. The first requirement is that a sufficient number of replicated measurements be made. This is necessary to make sure that the sample average will approximate the true value. The systematic structural variation within a given muscle introduces variations beyond those due strictly to normal random chance measurement errors. This inherent structural variation can lead to a widely deviant average if too few measurements are made. Secondly, the population studied should have sufficient numbers at the extremes. In other words, there should be a good representation at the extremely tender end of the scale and there should be a sufficient number of tough samples.

The Tenderometer developed through these efforts was found capable of quickly measuring difference in tenderness. The number of needles and their arrangement in a 1"x3" rectangle makes possible a replicated cross sectional measurement of tenderness of the rib eye. The size and economic importance of the *longissimus dorsi* makes this measurement significant in itself. However, work by Knutson *et al.* (1966) demonstrated that the rib *longissimus dorsi* is the best predictor of tenderness for the rest of the carcass. Thus, measurements with this instrument are indicative of the relative tenderness of the entire carcass.

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