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Comparison of Objective and Subjective Evaluations of Tenderness of Beef

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CONTENTS

SUMMARY

Data from several independent studies were analyzed to determine whether shear values obtained with the Warner-Bratzler shear and the L.E.E.-Kramer shear press correlated with taste panel evaluations for tenderness. Highly significant negative correlations between Warner-Bratzler shear and panel scores were obtained. However, significant correlations were not always obtained in the case of the L.E.E.-Kramer shear press, even though highly significant correlations occurred between Warner-Bratzler and L.E.E.-Kramer shear measurements for cores of meat from adjacent slices. The L.E.E.-Kramer instrument has potential as a measuring device for tenderness but need for further study of sample load of meat is indicated.

This bulletin is a report on School of Home Economics project 349, Improving the Acceptability of Meat

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INTRODUCTION

A difference of opinion exists among researchers concerning the use of shear values as an indication of tenderness of meat. Some investigators have indicated that the terms "shear strength," as measured by the Warner-Bratzler apparatus, and "tenderness" of the meat may not be synonymous (Deatherage and Garnatz, 1952). Also, Cover and Hostetler (1960) have pointed out that there is still a question as to the components of tenderness measured by shearing.

The Warner-Bratzler instrument is the most commonly used device for shearing meat. This apparatus was developed in 1928 by the men whose name it bears and was designed to measure force required to draw a steel blade through a standard core of meat (Schultz, 1957). The instrument has been modified for some studies, and it has been used to test either ½ or 1-inch cores of meat (Paul and Bratzler, 1955). One of the more recent modifications was reported by Spencer *et al.* (1961). These researchers used a horizontal form of the Warner-Bratzler apparatus equipped with a cantilever beam with strain gages on both sides instead of the spring scale. A recording system was added. Preliminary work with this modified Warner-Bratzler shear indicated that variation in results within samples was reduced.

Hurwicz and Tischer (1954), when using the Warner-Bratzler shear, determined (1) the maximum shear force, (2) the time necessary for failure in shear, and (3) the slope of the shear force vs. the time curve. These authors indicated that although the maximum shear force is most commonly reported, the slope of the force vs. time curve showed the greatest discrimination between treatments.

The more recently developed L.E.E.-Kramer shear press was first described for use in testing vegetables (Kramer *et al.*, 1951). This instrument employs hydraulic pressure to force a plunger connected with a series of metal plates through a shear cell containing the test sample. The force, which causes deformation of the proving ring of the instrument, is recorded and can be converted into pounds per gram of meat. Some of the L.E.E.-Kramer instruments are equipped with a device for recording the complete time-force curves. It has been proposed that an estimate of chewiness of beef may be obtained by shearing the same sample a second time (Kramer, 1961).

Burrill *et al.* (1962) compared tenderness of 82 cooked beef muscles by using the Kramer shear, the Warner-Bratzler shear, and taste panel. The findings indicated that maximum shear force determined by either the Warner-Bratzler or the Kramer shear instruments agreed reasonably well with taste panel evaluations of tenderness.

Table 1 summarizes several studies for which either the L.E.E.-Kramer or the Warner-Bratzler shear instruments were employed to obtain information about the tenderness of meat. Other instruments have also been used in an attempt to discover the one most suitable. Schultz (1957) described these instruments beginning with Lehman's mechanical devices of 1907 and extending through the Proctor, Davison, and Brady modification of the Strain-Gage Denture Tenderometer of 1956. Recently, a slice tenderness evaluator was designed which gave a correlation with taste panel scores similar to that of the Warner-Bratzler shear for cooked pork *longissimus dorsi* (Kulwich *et al.*, 1936). With this new device, the sample is first punctured and then sheared, and maximum values for the two measurements are recorded. Shearing parallel to the meat fibers gave higher correlations with Warner-Bratzler measurements than did shearing perpendicular to the fibers.

Attempts have been made to improve the technique for subjective evaluation of tenderness of meat. Cover *et al.* (1962) characterized six components of tenderness: softness to tongue and cheek, softness to tooth pressure, ease of fragmentation, mealiness, adhesion between fibers, and hardness of connective tissue. Paul (1962) and Burrill *et al.* (1962) reported number of chews required to masticate a standard size sample. Correlations, presented by Paul, between tenderness as measured by panel scores and by number of chews and chemical determination for collagen, elastin, and fat were not significant. Neither was fiber measurement found to be a good indication of tenderness as shown by correlation with taste panel scores, with number of chews, and with shear force. Burrill found higher correlations between panel scores and shear measurements than between number of chews and shear value.

The purpose of the study reported herein was to analyze data from several independent experiments to determine whether measurements from two objective testing instruments (Warner-Bratzler shear and L.E.E.-Kramer shear) correlated with, and could be used to predict taste panel evaluations for tenderness of beef. Effects of size and position of the sample in the L.E.E.-Kramer shear cell also were studied.

TABLE 1 - A SUMMARY OF SELECTED STUDIES CONCERNED WITH TENDERNESS OF MEAT AS MEASURED BY THE L.E.E.-KRAMER SHEAR, WARNER-BRATZLER SHEAR, AND SENSORY EVALUATION

Author	N	Grades	Cuts	Samples	Findings
Bailey et al. (1962)	Study A: 75	3	Loin	Adjacent steaks for panel and shear.	Highly significant overall negative correlations between Kramer shear and sensory tenderness for all steaks disregarding grades and cuts. Correlations within grades and cuts generally significant.
			Round	Panel: steaks 1 and 4. Kramer shear: steaks 3 and 6. 2 5/8-inch square sections from 3/4-inch steak, sheared parallel to fibers.	
	Study B: 183	2	Loin	Same as study A.	
			Round	Kramer shear: same as Study A. 2 adjacent steaks.	
Batcher et al. (1962) Batcher and Dawson (1960)			Longissimus dorsi muscle	Kramer shear: 20g sample in 1 3/8 x 7/8 x 1-inch cell.	Highly significant negative correlation between shear values on cooked meat and panel scores. Shear values on raw meat did not correlate with shear values on cooked meat or with panel scores. Significant correlations between Kramer and Warner-Bratzler shears on selected raw and cooked muscles.
Bratzler and Smith (1963)	129	2	Lamb loins	Warner-Bratzler shear: ½-in. cores for lamb, 1-in. cores for beef. Panel: 3/4-in. long ½-in. cores for lamb. ½-in. long, 1-in. cores for beef.	Highly significant negative correlation between shear and panel scores for beef shortloins, beef rounds, and lamb loins, but not between beef ribs and panel.
	7	1	Beef ribs		
	15	1	Beef shortloins		
	51	1	Beef rounds		

(more)

TABLE 1 - (CON'D.)

Author	N	Grades	Cuts	Samples	Findings
Burrill et al. (1962)	82	4	Round, rib sections	Warner-Bratzler shear: 1-in. cores 2½-in. long, 3 shears/core. Kramer shear: 1-in. cores 2½-in. long. Number of chews: ½-in. cubes. Panel: 1/8-in. thick slices adjacent to area used for shear cores.	Significant positive correlations between Warner-Bratzler and Kramer shear values, number of chews and Warner-Bratzler shear, and number of chews and Kramer shears. Significant negative correlations between Warner-Bratzler shear and taste panel evaluations, and Kramer shear and taste panel scores.
Cover et al. (1962)	180		Loin, bottom round	Warner-Bratzler shear: ½-in. cores.	Significant difference between Warner-Bratzler shear for loin cooked to 80°C and 61°C but not for loin and round cooked to 80°C and 100°C. Low correlations between Warner-Bratzler shear and taste panel scores for tenderness of connective tissue.
Fielder et al. (1963)	128	4	Loin, rib, bottom round, inside chuck	Panel and Warner-Bratzler shear: samples taken from 3/4-in. thick steaks.	Significant negative correlations between sensory evaluations and Warner-Bratzler shear for all cuts except swissed bottom round and inside chuck and over-roasted top round.
Hood (1960)	24	2	Shoulder	Warner-Bratzler shear: ½-in. cores. Panel: ¼-in. thick slices.	Significant differences in Warner-Bratzler shears and palatability scores between dry and moist heat cookery and between grades.

Korschgen et al. (1963)	Taste panel: 540, shears: 36	2	Shoulder clod, chuck roll	Warner-Bratzler: 1-in. cores. Adjacent slices for panel and shear.	No significant differences in panel scores for tenderness or in Warner-Bratzler shear values between broiled meat preroasted to two internal temperatures.
Kulwich et al. (1963)	61		Loin	Panel: $\frac{1}{4}$-in. slices. Warner-Bratzler shear: 1-in. cores, 3 shears/core.	Negative correlation between Warner-Bratzler shear values and taste panel scores for tenderness.
Rodgers et al. (1963)	Study A: 96	2	Top round	Warner-Bratzler shear: 1-in. cores. Panel: cubes from 1-in. thick slices.	No significant differences between Warner-Bratzler shear values or between panel scores for tenderness. Significant differences in shear values between grades but not in panel scores.
	Study B: 112	2	Top round	Same as Study A.	Significant difference between shear values for conventionally broiled meat and prebrown plus oven cooked meat but not between panel scores for tenderness. Significant difference for shear values and panel scores between grades of meat.
Rodgers et al. (1963a)	Study A: 64	2	Top round	Same as Rodgers et al. (1963)	Significant differences in Warner-Bratzler shear and panel scores between two dry-heat methods of cookery.
	Study B: 48	2	Top round	Kramer shear: 1-in. cores sheared across the fibers.	Highly significant difference in Kramer shears and panel scores between two dry-heat methods of cookery.
Taylor et al. (1961)	12	1	Rounds	Warner-Bratzler shear	Significant differences in shears only between steaks 1 and 2 anterior protions of semitendinosus and semimembranosus.

EXPERIMENTAL METHODS

Taste Panel Evaluation. All experiments were conducted using a six-member, experienced taste panel seated in individual booths in a specially designed air conditioned room. The panel composition differed among studies, but remained the same throughout individual studies. A nine-point rating scale was used for evaluating tenderness of meat, and for one study, the number of chews was recorded as well as the rating of tenderness.

Warner-Bratzler Shear. For all studies, 1-inch cores of meat were used to determine force for shearing by the Warner-Bratzler instrument, vertical model.

L.E.E.-Kramer Shear. One-inch cores of meat placed in the L.E.E.-Kramer shear cell so that the fibers were horizontal to the cell and perpendicular to the blades were used in all studies. Hereafter, these samples will be referred to as *perpendicular cores.* One study included 1-inch cores placed in two additional positions: (1) meat fibers vertical to the blades, referred to as *vertical,* and (2) meat fibers horizontal in the shear cell and parallel to the blades, referred to as *parallel* (Fig. 1). The instrument was operated as described by Rodgers *et al.* (1963).

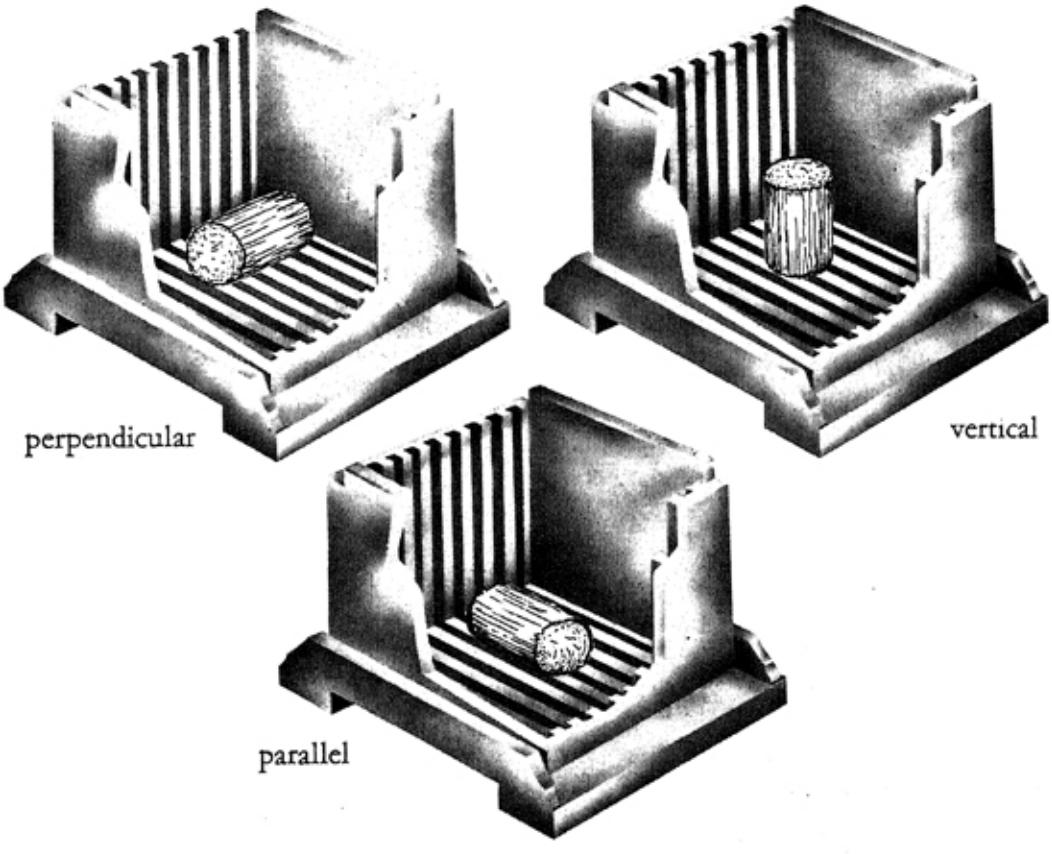


Fig. 1—Positions of 1-inch cores of meat in shear cell of the L.E.E.-Kramer press.

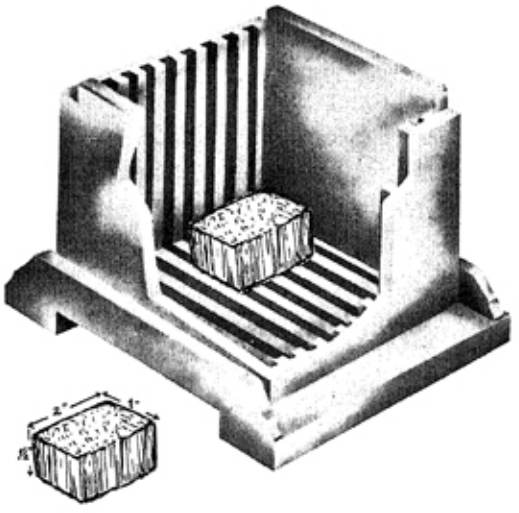


Fig. 2—Position of rectangular meat sample in shear cell of the L.E.E.-Kramer press.

Another study included shear values from rectangular pieces approximately 2 x 1½ inches cut from 1-inch thick slices of meat. One rectangle from each slice was weighed and placed in the shear cell so that the blades cut with the grain of the meat (Fig. 2).

Cuts of Meat. Data included values from shoulder cuts (shoulder clod and chuck roll) and from top round of beef. All shoulder cuts were prepared according to the roasteak procedure (Korschgen *et al.,* 1963). Top rounds were sliced and prepared by dry heat methods described by Rodgers *et al.* (1963). Although two grades of beef (U.S. Good and U.S. Choice) were used, data were not separated as to grade. All shear tests were conducted on meat at room temperature.

RESULTS AND DISCUSSION

Subjective Evaluation of Tenderness vs. Warner-Bratzler Shear Values. Table 2 summarizes the means and correlation coefficients between taste panel scores and Warner-Bratzler shear values obtained from three studies of top round and one of chuck roll. All "r" values were negative and significant at the 1 percent level or above. Thus it appeared that when meat was rated tender by the taste panel, lower shear values were obtained. In contrast, Deatherage and Garnatz (1952) stated that correlation was poor between taste panel evaluations and results from Warner-Bratzler shear. These authors suggested that higher correlations might be obtained if variations in meat were greater than in the shortloins compared in their study. There is no way of knowing whether the difference gradations for this study were greater or similar to those discussed by Deatherage and Garnatz (1952).

TABLE 2 - MEANS AND CORRELATION COEFFICIENTS BETWEEN TASTE PANEL SCORES[1] AND WARNER-BRATZLER SHEAR MEASUREMENTS FOR TWO CUTS OF BEEF

Study	Cut	Obser-vations[2]	Panel scores[3]	Shear values[3]	"r"
				lbs/1-in. cores	
1	Top round	95	5.2	24.5	-0.77***
2	Top round	112	6.3	32.0	-0.67***
3	Top round	64	6.9	25.1	-0.59***
4	Chuck roll	54	6.2	17.9	-0.41**

[1]Range of scoring: 1, low, to 9, high.
[2]Mean of 6 panel scores and mean of shears for 3 cores/observation.
[3]For top round, all determinations were made on the same slice. For chuck roll, panel scores and sheat values represent adjacent slices.

** Significant at 1% level.
*** Significant at 0.1% level.

Only in study 2 was the number of chews required to masticate the meat recorded as well as a rating for tenderness. A considerable amount of judge-to-judge variation was evident in number of chews, and it appeared that this type of evaluation was not reliable. Correlation was shown neither between number of chews and taste panel evaluation of tenderness nor number of chews and Warner-Bratzler shear values.

Subjective Evaluation of Tenderness vs. L.E.E.-Kramer Shear Values. The number of studies and observations made with the L.E.E.-Kramer shear press was not as large as for the experiments cited above for the Warner-Bratzler shear. In only one of three studies was a significant correlation found between the L.E.E.-Kramer shear press and taste panel scores for tenderness (Table 3).

TABLE 3 - MEANS AND CORRELATION COEFFICIENTS BETWEEN TASTE PANEL SCORES[1] AND L.E.E.-KRAMER SHEAR MEASUREMENTS FOR TWO CUTS OF BEEF

4	Cut	Observations	Panel scores	Shear values	"r"
				lb/g	
4	Chuck roll	54 Mean of 6 panel scores and 3 cores/observation	6.2	21.3[2]	-0.09
5	Top round	48 Mean of 6 panel scores and 2 cores/observation	7.2	18.1[2]	-0.72***
5	Top round	48 Mean of 6 panel scores and 1 shear/rectangular sample.	7.2	21.8[3]	0.23

1 Range of scoring: 1, low to 9, high.
2 One-in. cores placed so that the fibers were horizontal in the cell and perpendicular to the blades.
3 Rectangular pieces, 2 x 1½ x 1-inch, sheared with the grain (1-in. surface).
***Significant at the 0.1% level.

Although Bailey *et al.* (1962) did not find significant correlations between sensory scores and shear values for all studies, they did regard the L.E.E.-Kramer shear as a useful device for measuring tenderness of beef steak. These investigators did obtain significant correlations between panel scores and shear values for all U.S. Choice grade steaks. The importance of this was stressed by the authors in relation to the difficulty encountered in evaluating tenderness of U.S. Choice grade beef. Disregarding grade, an over-all correlation of -0.74 ($P<0.001$) between sensory evaluations and L.E.E.-Kramer shear values was found for 258 steaks tested by Bailey and co-workers. In the work reported herein, with 48 observations, a correlation of -0.72 was found between taste panel scores and L.E.E.-Kramer shear measurements for top round of beef. However, correlations of -0.09 and 0.23 were found, respectively, for 54 observations on chuck roll and 48 observations of top round (Table 3).

Sample Load for L.E.E.-Kramer Shear. With the sample sizes used in this study, differences in L.E.E.-Kramer shear values were not associated with a particular size and shape. When 1-inch cores were used, a significant "r" was obtained between shear values and judges' estimates of tenderness in the study of top round, but not in the study using cores from the chuck roll (Table 3). The correlation between taste panel scores and shear values for rectangular samples (2 x 1½ x 1-inch) of top round sheared with the grain was not significant.

Position of the cores within the L.E.E.-Kramer shear cell appeared to have an effect upon the force required to shear. A significant positive correlation oc-

curred in shear values between cores of chuck roll with fibers perpendicular to the blades and cores in a vertical position with fibers running parallel to the blades. However, no significant correlation occurred between perpendicular cores and parallel cores (Table 4, Fig. 1). Comparison of shear values between vertical

TABLE 4 - MEANS AND CORRELATION COEFFICIENTS BETWEEN CORE POSITIONS IN THE CELL OF THE L.E.E.-KRAMER SHEAR

Study	Cut	Obser-vations[1]	Core position: Perpen-dicular[2]	Core position: Verti-cal[3]	Core position: Parallel[4]	"r"
			lbs/g	lbs/g	lbs/g	
6	Chuck roll	54	22.5	1.0		0.36**
6	Chuck roll	54	20.3		15.5	0.15

[1] Mean of 4 cores/observation. Cores obtained from same position in adjacent slices.
[2] One-inch cores placed so that the fibers were horizontal in the cell and perpendicular to the blades.
[3] One-inch cores placed so that the fibers were vertical to the blades.
[4] One-inch cores placed so that the fibers were horizontal in the cell and parallel to the blades.

and parallel cores (Fig. 1) taken from the same slices of meat showed no correlation (Study 6: chuck roll, -0.04; shoulder clod, -0.02). All of these cores were sheared with the blades parallel to the fibers of meat. When fibers of the meat are parallel to the shearing blades the shearing action would be expected to be at a minimum, whereas with the fibers perpendicular to the shearing blades maximum shearing force would be expected (Kramer, 1960).

Bailey *et al.* (1962) and Burrill *et al.* (1962) obtained positive correlations with L.E.E.-Kramer shear values and sensory evaluations of tenderness when shearing respectively, 2⅜-inch squares from ¾-inch thick steaks and 1-inch cores which were 2½-inches long. Shearing was parallel to the meat fibers for the square samples. Investigators employing the L.E.E.-Kramer apparatus for chicken have randomly filled the shear cell with ⅜-inch cubes equivalent to 50 g dry solids. Three successive shears were applied to the sample and the values were averaged (Dodge and Stadelman, 1960; Seltzer, 1961; Stadelman and Wise, 1961).

Comparison of Warner-Bratzler and L.E.E.-Kramer Shear Measurements. Highly significant correlation coefficients (0.1% level) were obtained between the Warner-Bratzler and L.E.E.-Kramer shear measurements taken on cores of meat obtained from adjacent slices (Table 5). This is of particular interest because significant correlations were obtained in four studies between the Warner-Bratzler shear values and taste panel evaluations for tenderness of meat (Table 2), whereas only one out of two studies comparing the L.E.E.-Kramer shear values for 1-inch cores and subjective scores was significant (Table 3).

TABLE 5 - MEANS AND CORRELATION COEFFICIENTS BETWEEN WARNER-BRATZLER AND L.E.E.-KRAMER SHEAR MEASUREMENTS OF ADJACENT SLICES OF BEEF

Study	Observations	Cut	Warner-Bratzler	L.E.E.-Kramer[1]	"r"
			lbs/1-in. core	lbs/g	
5	48[2]	Top round	25.5	18.1	0.51***
6	108[3]	Chuck roll	16.5	20.9	0.47***

[1] One-in. cores placed so that the fibers were horizontal in the cell and perpendicular to the blades.
[2] Mean of 6 panel scores and 2 cores/observation.
[3] Mean of 6 panel scores and 4 cores/observation.
*** Significant at the 0.1% level.

Only a few studies have been found in which comparisons were made between the L.E.E.-Kramer and Warner-Bratzler instruments. Included are those of Burrill *et al.* (1962), Batcher *et al.* (1962), and Webb (1959). In each study, positive correlation coefficients between the two instruments were found. Webb (1959) compared three sample loads: (1) fourteen cubes from ¾-inch steaks placed at random in the cell, (2) squares, 2⅜-inches, cut from ¾-inch thick steaks, sheared parallel to the fibers, and (3) slices, ½-inch x 2⅜-inches from ½-inch thick steaks sheared perpendicular to the fibers. The third procedure was found best adapted for comparison with Warner-Bratzler shear.

Location of Cores for Shearing. No significant difference was found by analysis of variance (108 observations) among L.E.E.-Kramer shear values for cores taken from four locations in slices of chuck roll and sheared in the perpendicular position (Figs. 1 and 4). In Table 6, correlation coefficients are given

TABLE 6 - COMPARISON OF INSTRUMENT PERFORMANCE WITH CORES FROM ADJACENT SLICES OF SHOULDER CLOD

Study	Instrument	Observations[1]	Mean	Mean	"r"
			slice 3	slice 4	
6	L.E.E.-Kramer (lbs/g)[2]	71	18.0	17.2	0.82***
			slice 7	slice 8	
6	Warner-Bratzler (lbs/1-in. core)	72	13.6	13.7	0.65***

[1] Mean of 4 cores/observation.
[2] One-in. cores placed so that the fibers were horizontal in the cell and perpendicular to the blades.

*** Significant at the 0.1% level.

for cores of beef taken from adjacent slices and sheared with the same instrument. Since, for each instrument, highly significant values were obtained between slices, use of adjacent slices for objective and subjective measurements appears to be a reasonable procedure at least in the case of slices from the middle portion of the shoulder clod (Fig. 3). This procedure might also be compared to the technique of obtaining more than one shear value per core as reported by Burrill *et al.* (1962), Kulwich *et al.* (1963), and Webb (1959).

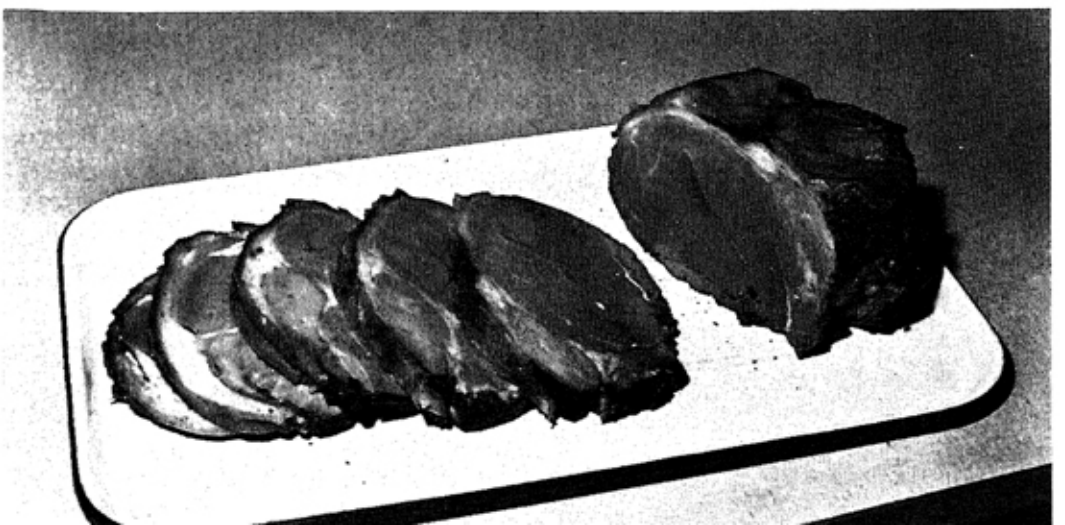
Other investigators have been concerned with tenderness within the same muscle of meat, although location of cores for shearing was not the major concern. For shear measurements on round of beef, Taylor *et al.* (1961) discovered significant differences only between the first and second steaks cut from the *semitendinosus* and *semimembranosis* muscles. Variation in shear values from end to end of the *semimembranosis* muscle was reported by Paul and Bratzler (1955). Greater steak to steak variation was pointed out by Ginger and Weir (1958) for the *semimembranosus* muscle than for the *biceps femoris* or the *semitendinosus,* the latter of which was found to be the most uniform muscle of their study. In view of the findings of these researchers it would appear that caution should be exercised in determining the relative position of samples for taste panel and shear measurements for various muscles of beef.

IMPLICATIONS

The findings from this study indicate that maximum shear, as measured by the Warner-Bratzler apparatus, gives reasonable agreement with sensory evaluations for tenderness of meat. Low shear values were associated with meat which was rated as tender by taste panel members. The newer modifications of the Warner-Bratzler shear apparatus may increase its sensitivity and reliability even further (Spencer *et al.,* 1961).

Number of chews required to masticate a meat sample appears to be a less reliable technique for judges than a numerical rating of tenderness.

Fig. 3—Shoulder clod of beef.



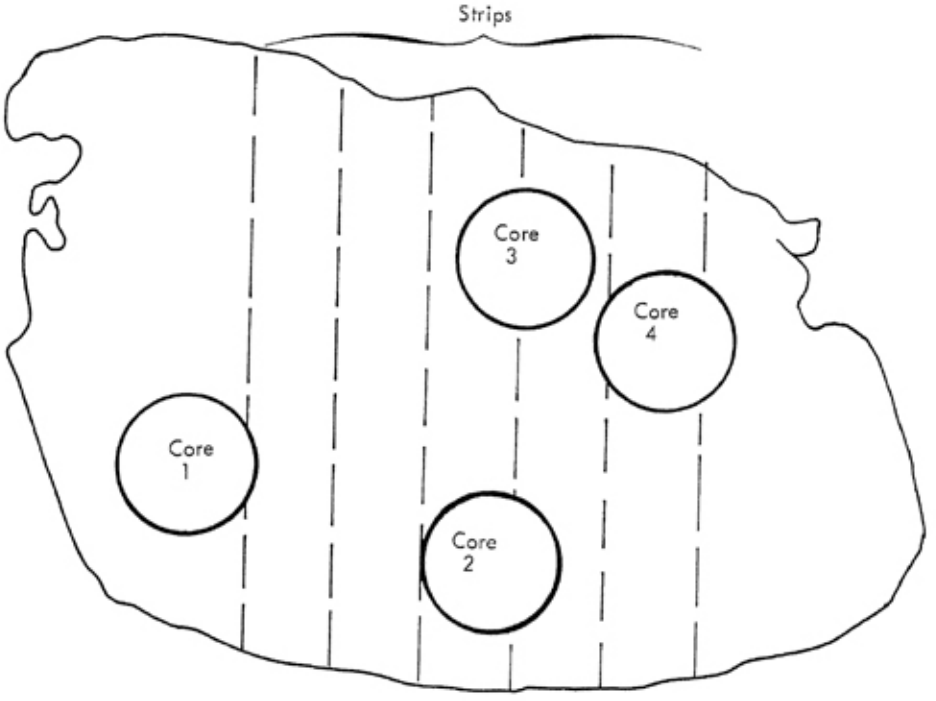


Fig. 4—Tracing of one slice from the chuck roll showing locations of strips used for taste panel and cores for shearing.

The L.E.E.-Kramer shear press appears to have potential as a device for objective testing of beef, but further study in relation to sample load is needed before it will be as useful as the Warner-Bratzler shear. Standardization of the procedure for use of the press would aid in comparing and interpreting data from various laboratories.

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