THE SYSTEMATIC VARIATION IN TOUGHNESS WITHIN MUSCLE AND SOME OF ITS IMPLICATIONS

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The heterogeneous structure of natural foods has given rise to the development of a number of empirical mechanical devices for evaluation of texture. The lack of homogeneity in biological materials would lead one to expect some difficulty in getting reproducible texture measurements. For example, the structured nature of muscle would tend to prevent one from obtaining the consistency among replicates on a given sample that would be expected in measuring a more homogeneous food such as jelly, processed cheese, margarine, etc.

The customary approach in mechanically testing the tenderness of a meat sample is to make a number of replicate determinations and average them. The expectation is that true differences between different samples will be demonstrated.

The fact that different muscles in a carcass tend to follow a rather consistent pattern with some being tougher and others more tender is well known. But, beyond this, end-to-end variation in tenderness within a given muscle has also been demonstrated (Ginger & Wier, 1958; Paul & Bratzler, 1955; Ramsbottom et al. 1945) as well as variation of tenderness at different locations upon a given cross section of the muscle (Alsmeyer et al. 1965; Hedrick et al. 1968; Tuma et al. 1962). These variations have been indicated using tests like the Warner Bratzler shear device.

The Warner Bratzler shear device has been used extensively to evaluate tenderness. The details of the test procedure such as cooking method, temperature of samples when tested, core diameter, positions where cores are taken from the sample, number of shear determinations made and averaged etc., varies somewhat between investigators. The shear test results however are usually analyzed by a statistical technique which assumes that variations in shear determinations on a given sample are normally distributed. This assumption implies that the material sheared does not contain systematic variation in texture.

As pointed out above, however, muscle is not homogeneous in texture, but contains a structured pattern of variation in tenderness. Practical attempts employed to get around this variability are to take core samples from prescribed locations and to avoid obvious visible connective tissue.

Statistical analyses of data are generally done using classical methods with the assumption that the statistical method will be sufficiently robust to handle failure of measurement errors to conform to strict normality. It appears, however, that these assumptions may at times contribute to some confusing ambiguities.

The purpose of the experiment reported here was to study the variation of shear determinations within the longissimus dorsi of the beef short loin and to get an indication of how this variation affects precision of results when different numbers of shears are used per sample.

A U.S. Prime short loin with a longissimus dorsi of quite a large cross sectional area was obtained. Six two-inch thick slices were cut from this loin and roasted in a 350°F oven to 150°F internal. After chilling to 40°F, the maximum possible number of good one-inch diameter cores were taken from within the longissimus dorsi muscle. This number varied from seven to nine. Three shears were made per core. Consequently, from 21 to 27 shear determinations were obtained per slice. A total of 150 shear determinations were obtained from the entire short loin.

The results of the shear measurements are summarized on a graph in Figure 1. The bars of the histograms indicate the number of shear determinations which occurred at the different pounds of force required. The values were grouped into groups at one-pound intervals. Since shear force was read to the nearest one-fourth pound, shear values of 9.5 to 10.25, for example, were grouped in the ten-pound bracket.

A technique for smoothing out sparse data to yield a frequency distribution (Schlaifer, 1959) was applied to try and smooth out the actual sample values. The results of these computations are indicated by the dots in Figure 1.

A normal curve was also fitted using the mean and standard deviation of the total data in the equation for the normal curve (Dixon and Massey, 1957). This fitted curve is drawn as the smooth bell shape curved superimposed on the histogram at the bottom of Figure 1.

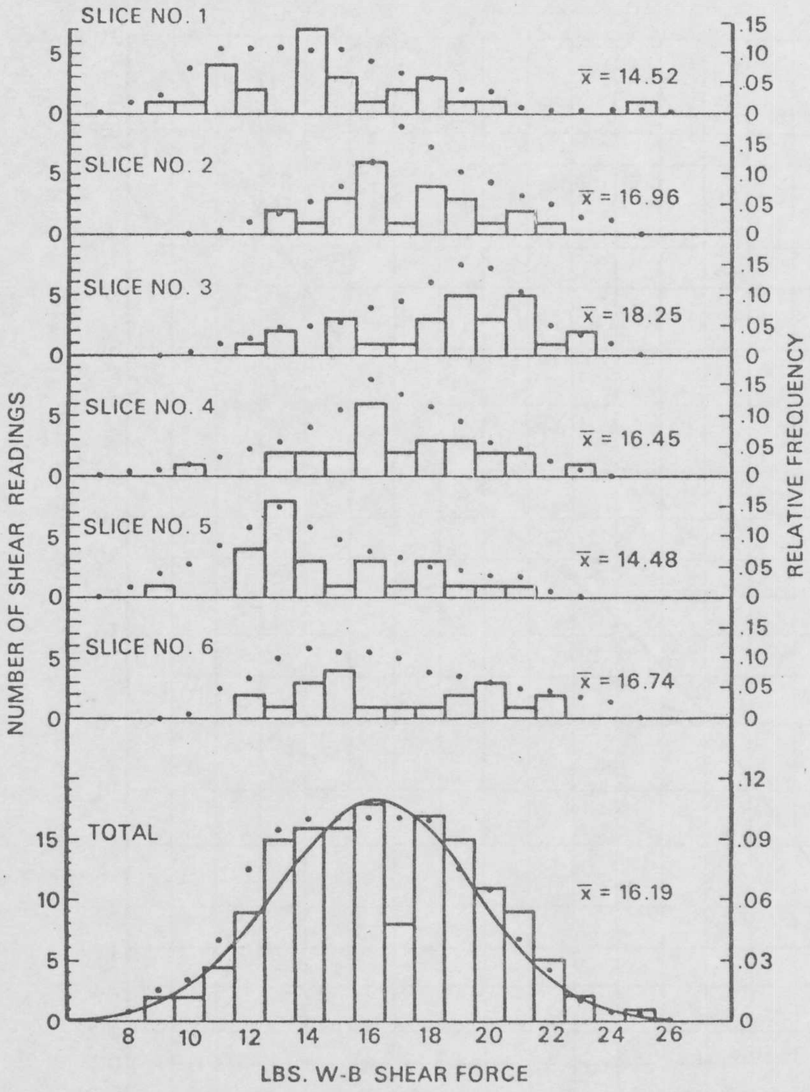
Some initial observations can be made viewing the results in this form:

(1) Shear values within a given slice tended to be spread out over a rather broad range.

(2) The small mode peak that was present in each slice was not necessarily centrally located.

(3) The overall picture was a frequency distribution for the entire short loin with a somewhat flattened top. In other words, the frequency of observed shear readings at or near the mean was less, and the frequency of shear readings deviating moderately from the mean was greater than what would be expected with the assumption of a strictly normal distributed population.

Figure 1. Distribution of shear determinations in six slices from one short loin.



Some tests of normality were made. In Figure 2 the cumulative relative frequency of shear values are plotted on normal probability paper. If the distribution were strictly normal, the line would be straight. In Figure 3 mean shear values of adjacent pairs of cores within slices were plotted. If the distribution were normal, there would be a more dense clustering of points near the mean but getting gradually more diffuse away from the mean. While the points are closer together near the mean, there appears to be a systematic linear pattern departing from the mean.

Figure 2. Plot of Individual shear determinations from one short loin.

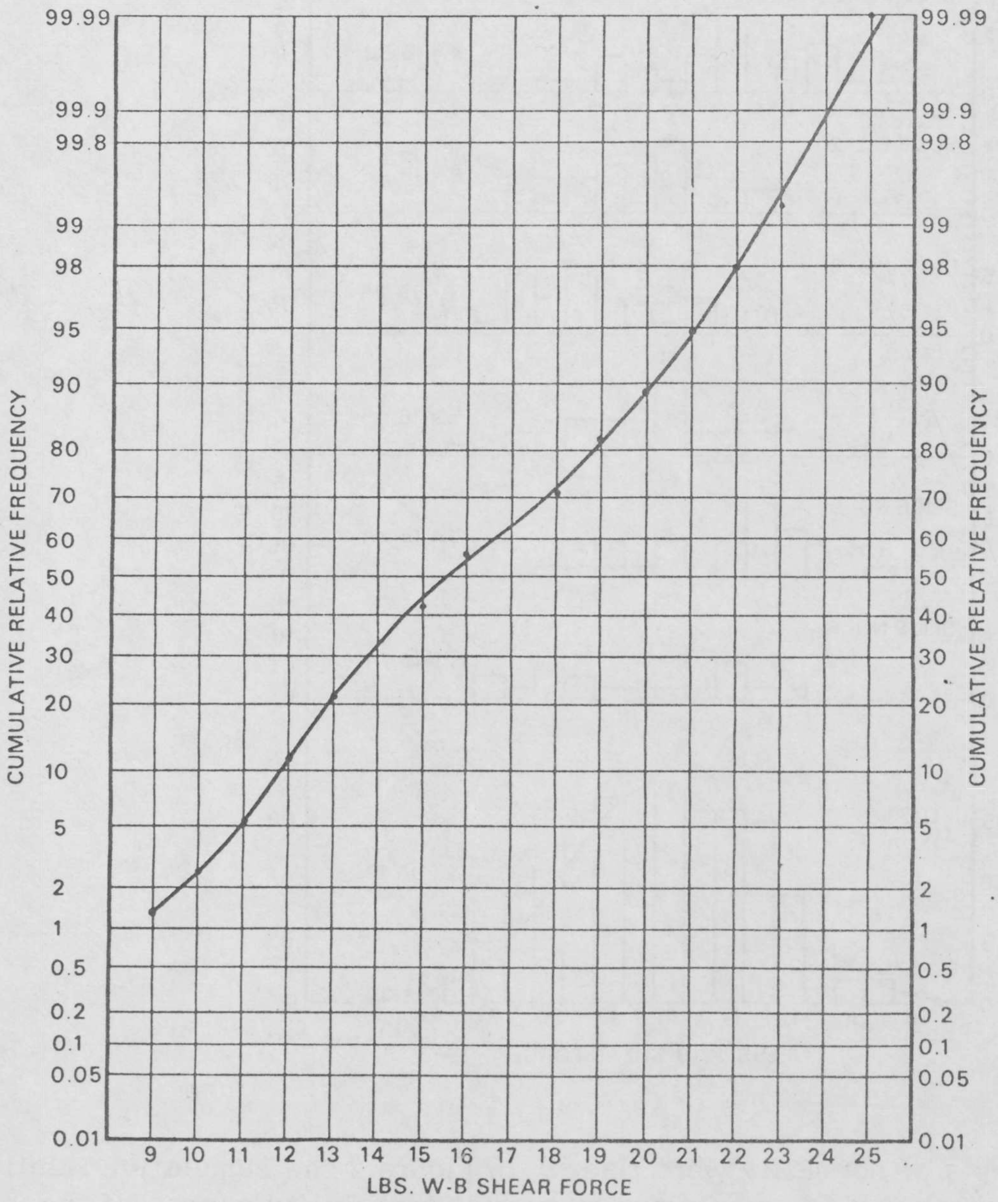
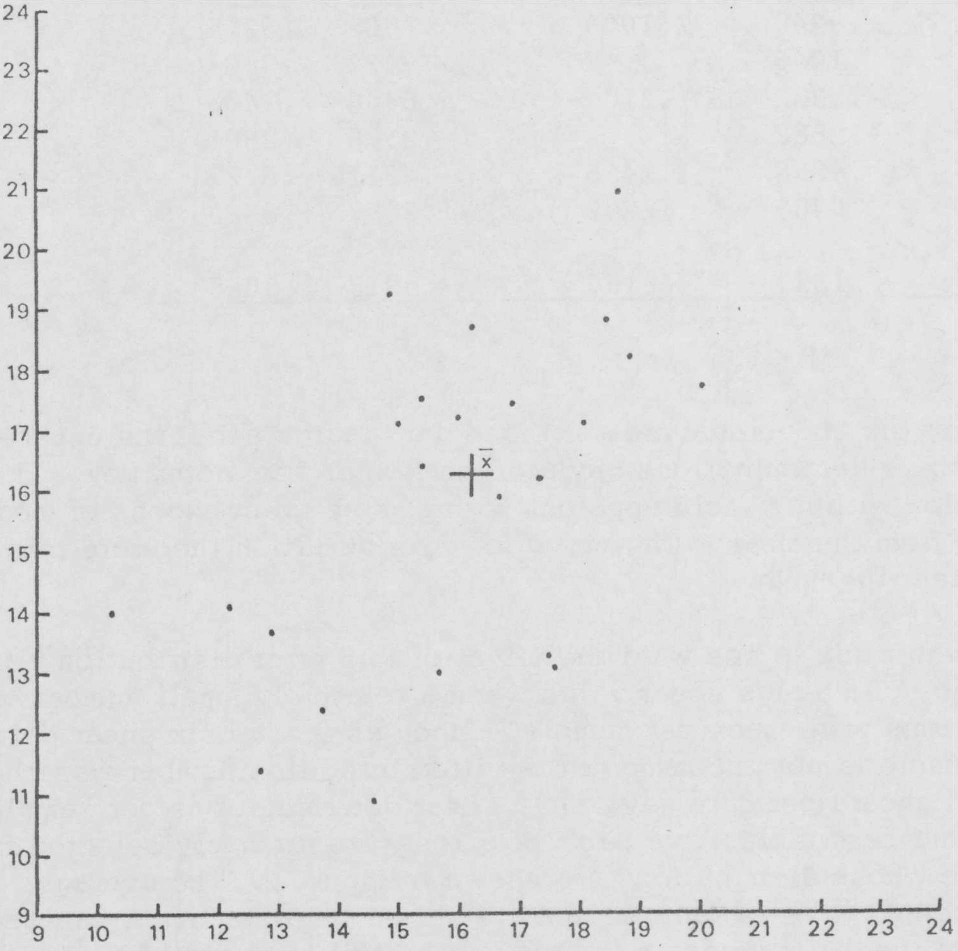


Figure 3. Mean shear values from adjacent pairs of cores from within one short loin.



Since the above two tests for normality involve subjective judgments, some quantitative tests were tried. The results of tests for skewness and kurtosis are summarized in Table 1. The g_1 values bear out what was visually observed in Figure 1, i.e. the pattern of skewed asymmetry was not consistent between slices. The calculated t values do not indicate that skewness is a significant factor in explaining departure from normality.

The g_2 values were more consistent. All but one of these were negative indicating an excess of measurements deviating moderately from the mean. The calculated t values for kurtosis were not large enough to demonstrate significance however.

Table 1. Tests for Symmetry and Normality

	Skewness		Kurtosis	
Slice	g_1	t	g_2	t
1	.9249	2.100*	.7085	.8255
2	.1046	.2296	-.9472	1.068
3	-.5332	1.210	-.6408	.7466
4	-.2568		-.2526	.2801
5	.4358	1.2456	-.4911	.5722
6	.0455	.2202	-1.2557	1.8685
Overall	.1599	.8100	-.5918	1.5085

*$P < .05$

As a whole, the above analyses of these data indicate that the experimental error in shear determinations deviates somewhat from normality. The structural variation within muscle apparently gives rise to an excess of moderate deviations from the mean. The curve for error variation therefore tends to be more flat near the mean.

An effort was made to see what the effect of this error distribution was on the consistency of average shear value when a relatively small number of shear determinations were made per sample. Since as few as six shear determinations per sample is not uncommon in the literature, this number was chosen. Two cores with 3 shears per core gave the 6 shear determinations per sample. Using a random numbers table, five pairs of cores were randomly selected from within each slice whose distributions are shown in Figure 1. The average shear values obtained were calculated and are shown in Table II. It can be seen that some of the differences are rather substantial in magnitude. The range of differences within slices varied, but the average range was 3.8 pounds. The most extreme shear values within the whole loin were 11.54 and 20.29 or a range of 8.75 pounds.

Table II. Average shear force from two cores* randomly chosen from within a slice.

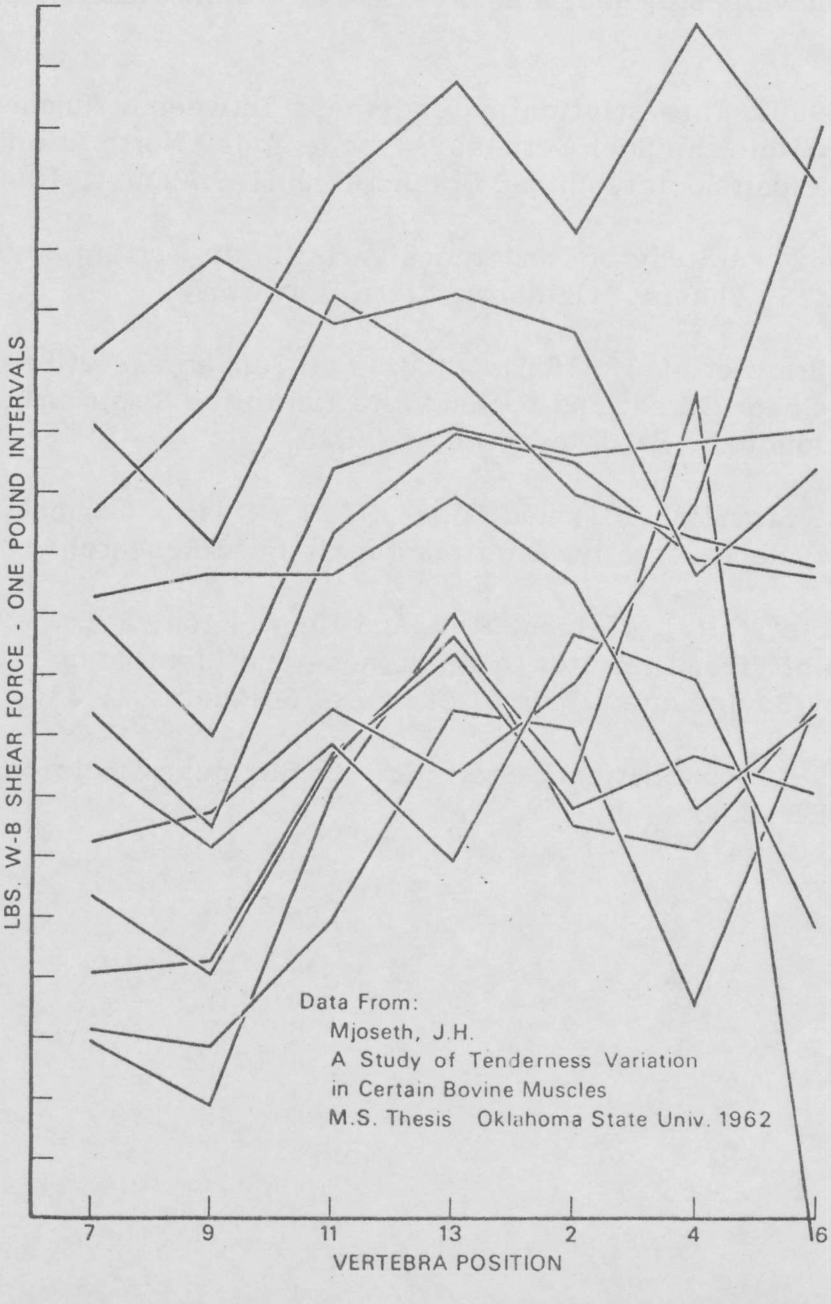
						Range
Slice 1	12.12	17.21	11.54	16.00	13.08	5.67
2	16.29	16.75	16.54	16.79	17.75	1.46
3	16.91	19.71	15.87	20.29	18.58	4.42
4	16.04	14.71	17.58	17.75	17.29	3.04
5	14.04	14.67	14.24	14.29	17.25	3.21
6	14.29	15.91	18.75	19.29	15.54	5.00

*3 shears were made per core so each value is an average from 6 shear determinations.

Since only one short loin was involved in this test, further confirmation would be desirable. Some corroboration may be found in a thesis by Mjoseth (1962). He reported shear values of cooked steaks from the longissimus dorsi through the rib and loin areas. He used 3 one-inch cores and 3 shear per core, i.e. 9 shear determinations per steak. The data in one of his tables are plotted in the graph in Figure 4. The erratic jumps in the curves suggest that significant amount of experimental error is obscuring the true condition.

In conclusion, the work reported here supports the statement of Kinsman (1960) "Observing the shear data one is impressed with the variation in shear values that occurs within a given muscle." The recommendation he gave that "...the number of cores per steak or muscle should be as many as feasible to not only randomize location but also to help average out extreme values." should also be given serious consideration.

Figure 4. Variation in shear force over length of longissimus dorsi.



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