(SESSION IV)

RECENT DEVELOPMENTS IN THE ANALYSIS OF MEAT TEXTURE

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Early meat research placed emphasis on quantity characteristics of production but more recently studies have been directed toward the quality aspects of meat. These attributes are naturally of more interest to the consumer since color, flavor, tenderness and juiciness are readily discernible to the senses. Modern research has allowed us to define these parameters, measure, predict and improve them and relate them to physiological and biochemical events taking place in the tissue.

Today, I will be dealing with just one palatability factor-texture-but consumer studies have indicated that this is the most important determiner of meat acceptability. Meat texture may be defined not in terms of coarseness or fineness of the muscle fiber bundles but more broadly and as is done for other food products as the mechanical properties of the tissue and, as such, it should be able to be measured objectively. Tenderness, on the other hand, implies a subjective evaluation and ultimately must be assessed organoleptically via such characteristics as juiciness, ease of tooth penetration and the amount of residue after chewing. Thus the overall impression of tenderness includes texture and these sensory aspects.

The texture of meat, that is its mechanical properties, is a function of structure and composition. Meat has the most complex structure of any foodstuff and for this reason measuring meat texture and interpreting the results is difficult and confusing.

Also, of course, muscles vary in composition and structure among the over 300 anatomically distinct units found in the musculature of the three common domestic species.

Much has been learned recently about muscle structure that should prove useful to those involved with meat texture. Both the transmission electron microscope and the scanning electron microscope (SEM) has contributed to our knowledge in this area. The latter instrument is well-suited for studying both the surface of muscle fibers and, with fracturing techniques, internal structure as well.

One aspect of meat texture that has been documented using the SEM is the aging phenomenon in beef muscle. We have looked at the development of structural changes in aged bovine psoas muscle (Eino and Stanley, 1972). This muscle was chosen since it has little connective tissue and allows the underlying structure to be seen directly. Fixation was in 10% formalin; samples were subsequently coated with gold. A micrograph of pre-rigor muscle fixed 2h post-mortem shows intact fibers and pronounced elevated transverse elements with smaller elements lying in the groove between them. These structures have been interpreted as either raised A bands with Z-lines lying in the resultant of the depressed I band (Stanley and Geissinger, in press) or the consequence of a network of sarcoplasmic reticulum covering the Z-lines and I bands (Schaller and Powrie, 1971). In some cases the sarcolemmal sheath is removed during sample preparation exposing the underlying myofibrils. These also show the predominant transverse elements.

At day 2 of aging a slight but noticable flattening of the transverse ridges had occurred while by day 4 an almost plane surface was observed.

By day 5 transverse fissures were becoming apparent and the extent of this damage increased steadily throughout aging so that at day 12 extensive fiber breakage may be seen. When broken fibers are viewed with the SEM the eveness of the break suggests that all the myofibrils had broken at the same point along the sarcomere, probably at the Z-line.

Other investigators have examined skeletal muscle with the SEM and the work of Schaller and Powrie at the Department of Food Science, University of British Columbia with cryofractured samples of fish, turkey and beef also showed changes in transverse elements in aged samples (Schaller and Powrie, 1971). The results obtained thus far with scanning electron microscopy indicate that this instrument should continue to provide valuable information about meat structure.

The most common question asked concerning meat is "How tender is it?" This actually means the simultaneous subjective assessment of the several characteristics mentioned previously. Unfortunately, none of the objective methods devised thus far have succeeded in exactly replacing the human senses in their ability to evaluate and describe meat tenderness. At present perhaps the most widely used technique for subjectively measuring tenderness has been the use of hedonic scoring for flavor, juiciness, tenderness and over-all acceptability. Usually between 3 and 12 panelists are used and samples are graded on a scale varying from possibly 'like extremely' to 'dislike extremely' which is subsequently transformed into scores from 1 to 10. The psycological error of 'central tendency' is commonly encountered in this type of scoring. This is reflected in an adversion of the judges toward using the extreme values of a scale. It is likely that this difficulty may be partially overcome by using an unstructured scale, for example the panel may be asked to place a tick on a horizontal line connecting points representing extremely tough and extremely tender at a location corresponding to their opinion of the sample tenderness. This type of scale was used by us in a recent study aimed at predicting cooked meat tenderness from physical properties of of the raw tissue (Stanley et al. 1972).

Two other points concerning subjective evaluation came up during the course of this investigation that may be of interest to this group. The first is chosing a subjective panel. It has been correctly pointed out that the quality of the panel and the validity of its evaluation depends on the selection and training procedures employed (Szczesniak and Torqeson, 1965). In this work we selected 10 panel members from 25 subjects on the basis of their ability to discriminate between cooked shank and tenderloin samples as well as their competency in pairing these tough and tender cuts. Subjects were given four samples, two of each cut, and asked to evaluate them for tenderness, elasticity and chew count on an unstructured form. Those who recorded the largest difference between shank and tenderloin and who had the smallest difference between duplicate samples were selected as panel members.

The second point is the use of standard samples. In addition to the meat each judge also received a sample of rehydrated unflavoured texturized soy protein. The panel was told that the standard sample was to be the same at each testing session and to judge the meat samples relative to the standard and not each other. It was hoped that the standard would be useful in decreasing differences among panel members and in providing continuity between panels. When this was checked statistically it was found that for the tenderness and elasticity test correcting the data by subtracting the value for the standard did not improve correlations with objective methods but a very dramatic increase was seen with the chew count test in which the panel was asked to record the number of uniform chews required to obtain a consistency at which the sample would normally be swallowed. When the value for the standard was subtracted from that of the sample a large improvement was noted (uncorrected, $r=-.07$; corrected, $r=.76^{**}$). Thus it appears that the use of a standard does improve panel continuity in this test.

Often the data from subjective tests are correlated with objective analyses. In this case it must be borne in mind that while objective measurements are usually made with instruments that give data from a ratio scale, that is from a scale which has a true zero point as its origin and the ratio of any two points on the scale is independent of the unit of measurement, taste panel results can be taken as having come from methods based on ordinal or ranking scales that do not assume these conditions. Hence it becomes much more valid to use non-parametric statistics. The Kendall correlation coefficient, based on rankings of the data rather than absolute differences, seems much more valid for these situations than the corresponding parametric test (Pearson's correlation coefficient).

Many pitfalls await those attempting instrumental-sensory correlations (Szczesniak, 1968,1972). Another approach to assessing the relationship between these data has recently been advanced by Larmond and Petrasovits at the Canadian Department of Agriculture in Ottawa (Larmond and Petrasovits, in the press). Rather than using correlations the relationship between objective and subjective data was characterized by estimating the probability that the panel would detect a given difference in shear values. This technique as well as the non-parametric method mentioned earlier eliminates the necessity of assuming a normal distribution which is usually violated since panel scores are often restricted to 10 or less possible values when hedonic scoring is used.

Briefly, this method consists of presenting judges with paired samples and asking for their evaluation or to which is tougher. Each sample is also measured objectively, for example peak shearing force with the Warner-Bratzler shear. These data are then subjected to probit regression analysis which allows calculation of the probability of agreement between objective and subjective analyses for a given difference in peak shearing force. This varied from 50% for a height difference of zero to 90% for a difference of around 1.5 kg to 99.99% for a difference of around 4.5 kg. The model was found to give a good fit for paired comparison data obtained from beef longissimus dorsi and semimembranosus muscles and the authors concluded that the objective methods employed could predict tenderness assessments by a sensory panel and the probit statistical analysis was useful in estimating the extent to which shear values can be used as predictors of tenderness.

There have been a myriad of ways developed for objectively measuring meat texture. Presently, the most widely used objective method used involves means by which force is applied across muscle fibers via a blunt edge and the amount of force required to shear the sample is recorded. The Warner-Bratzler Shear, first described in 1928, is still the most commonly employed instrument for objective testing of meat. This procedure is open to criticism on several grounds and reported correlations between Warner-Bratzler Shear values and taste panel results vary from no significance to very high significance. Such variables as orientation of muscle fibers, sample temperature, speed of shearing and blade dullness are difficult to control. Usually only the maximum shear force is measured and not the slope of the shear force curve which has been suggested to be more meaningful although it should be mentioned that the results of Larmond and Petrasovits indicated that maximum shear force was a better predictor of taste panel response that slope. Shearing devices are inherently empirical in nature and it is not clear that these instruments measure the same characteristics in meat as do sensory panels. Perhaps the most serious theoretical objection has been raised by Pool and Klose (1969) who suggest that meat samples subjected to shearing stress are distorted to the point that part of the applied shear force is altered to a tensile stress of the stretching fibers. The separation of fibers is thus due more to tensile force perpendicular to the blade than shear force parallel to the blade.

It is clear from this brief discussion that the Warner-Bratzler apparatus has limitations in its usefulness. Voisey and Hansen (1967) at the Canadian Department of Agriculture have updated the basic Warner-Bratzler design by producing an instrument that records the force required to continuously deform the sample using a constant but changable motor driven drive. The shearing force is detected by strain gages and their output is amplified and fed to a strip chart recorder. This allows maximum information to be gained since it provides data on maximum force (force of rupture), initial slope and work of rupture (area under force-distance curve).

Another traditional instrument of the shearing type is the Kramer Shear Press which when equipped with the shearing cell consists of 10 bars that are driven downward by a hydraulic drive through the sample which is held in a box having a corresponding number of slots on the bottom through which the bars extrude portions of the sheared sample. Besides the problems mentioned previously this apparatus confounds compression and extrusion with shearing. Szczesniak et al. (1970) have pointed out that with many food products including meat a non-linear relationship exists between sample weight and both maximum force and peak area.

Thus, at present most of the objective methods used for meat tenderness use some form of a shearing device and record the force required to shear or compress a given amount of sample across the muscle fibers. An instrument which allows the application of force parallel to the fibers is the Instron Universal Testing Machine and others of this type including the Ottawa Texture Measuring System devised by Voisey (1971). These instruments allow measurement of the force and work required to pull meat apart or stretch it and the amount of elongation the sample undergoes prior to rupture. The use of this instrument for evaluating meat tensile properties has been described by Stanley et al. (1971) and by Bouton and Harris (1972).

The Instron tester can also be used for other objective methods of meat texture. The slice-tenderness evaluation developed at the United States Department of Agriculture in Beltsville, Maryland (Kulwich et al,1963) consists of a sample holder in which a slice of meat is mounted and a penetrator that first punctures and then shears a portion of the tissue. Another method has been advanced by Pool (1967) at the United States Department of Agriculture in Albany, California. This technique measures the cohesive force holding muscle fibers together which has been termed connective tissue tenacity. This parameter was closely correlated with alkali insoluble hydroxyproline and inversely related to cooking time of poultry meat. The procedure calls for plugs of muscle to be glued to small plates perpendicular to the grain and the work required to pull the plates apart is measured with an Instron.

Although time does not allow a further discussion of the recent advances in physical methods of measuring meat texture such as the Armour Tenderometer (Carpenter et al., 1972) or the rotating dull knife tenderometer (Anderson et al., 1972) a new instrument that may prove useful for meat measurements should be mentioned briefly. This is the rotational rheometer which has the capability to detect torque and force in three directions through the use of multiple-stress detecting transducers (Macosko and Starita, 1971). Stress is applied to the sample through an upper and lower rotating spindle. Various rotating geometries including eccentric modes may be used and stress can be applied in either a steady or dynamic manner. It could be that the steady or dynamic deformation of meat in a torsional shear type of test may prove a useful method for tenderness.

While physical tests have been the most widely used for meat texture, chemical methods have also been developed. Work by Khan in the Food Technology section of the National Research Council of Canada has established that the pH of beef immediately after slaughter is indicative of how tender the meat will be and how long it will require to age (Khan and Lentz, in the press). The pH measurements are made as soon as the carcasses are split and are taken on the muscles exposed during splitting. It has been found that meat from carcasses having pH values between 6.6 and 7.1 will generally be tender and require only four to six days of aging while meat from carcasses in the range of 5.8 to 6.2

will be less tender and require longer aging.

Renewed interest has been given to connective tissue measurements in meat as indicators of tenderness. Although many previous studies have shown that hydroxyproline assays alone are not a good predictor of either taste panel scores or mechanical results, recent work utilizing methods that give more detailed information about the collagen molecule appear promising as a test for tenderness. Researchers at the University of Wyoming (Kruggel and Field, 1971; Pfeiffer et al., 1972) have presented data that suggest that aging beef muscle alters the molecular structure of intramuscular collagen and that a significant correlation exists between the quantity of each collagen chain component and muscle shear values. Aging decreases the amount of collagen cross-links and shear values decrease with decreased cross-linking.

Time has of necessity limited this presentation to a brief description of a few of the more recent developments in the objective and subjective analysis of meat texture. Many noteworthy contributions have, regretfully, been left unmentioned. To sum up, let me cite what I feel are several significant trends that have become apparent in this area: 1) subjective methods are becoming more statistical in approach and alternatives to parametric correlation coefficients are being sought and used. Although not mentioned directly, the texture profile panel (Szczesniak and Torqeson, 1965) appears promising as a technique for quantitating the complex subjective parameters involved in meat tenderness. This method seems to have achieved some degree of acceptance in industry. 2) objective instrumentation is proliferating and changing from a commodity orientation to a multipurpose orientation. Operating parameters are better known and more easily controlled. This may help to achieve some sort of standardization between laboratories, a badly needed improvement over the current situation. 3) the realization has occured that if meat texture measurement is to become anything more that an empirical science we must have a better understanding of the relation of structural properties to texture. Texture in food is the result of the spatial arrangement of compositional elements. Although muscle composition has been elucidated, emphesis must now be placed on unraveling the complex structure-texture relationships of meat. 4) A tacit corollary of this premise is that since texture of meat is assuredly not a consequence of only one factor several different types of measurement will be required to fully decribe it. Factorial analysis and multiple regression analysis will then enable the calculation of the relative importance of each measurement in prediting panel responses.

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