Methods for the Objective Measurement of Meat Product Texture

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INTRODUCTION

The texture of meat is undoubtedly the most important of those properties appreciated by the consumer and hence its prediction and control are vital to the industry (Harries et al., 1972). Use of appropriate instrumental methods to evaluate meat texture can provide valuable information concerning this sensory characteristic and product performance-type properties. Sensory texture refers to the physical characteristic of the meat product that is related to the palatability of the product upon consumption. Texture, in terms of product performance-type characteristics, would involve such properties as sliceability and formability. In order to encourage uniformity of data collection and reporting, this paper will focus on the latest advances in the physical methods to assess meat texture. Several excellent reviews on the general topic of instrumental methods of texture measurement have been published (Berry, 1983; Bourne, 1982a and 1982b; Hamann, 1987; Herring, 1974; Szczesniak and Torgeson, 1965; Voisey, 1976).

Before addressing the various methods to assess meat product texture, a brief discussion on how to define texture is pertinent. Stanley (1976) suggested that meat texture could be defined more broadly as the mechanical properties of the tissue. This is probably an acceptable starting point as long as the focus is on the physical-type traits and not other traits such as juiciness that are often evaluated with sensory texture.

Assessing meat texture can be achieved by sensory evaluation and instrumental means. Trained sensory panels and instrumental methods are often used as diagnostic tools to determine the impact of alterations in post-mortem technologies (application of exogenous proteolytic enzymes, optimization or activation of endogenous enzyme activity, carcass suspension methods), processing, non-meat adjuncts, temperature and storage time on product texture. In addition, trained sensory panels attempt to characterize meat products in terms of distinct traits. The terminology developed by trained panels is often used in interpreting results from instrumental texture determinations. Regardless of the objective method used, a high correlation with the consumer evaluation of the meat product texture is an essential requirement. Harris (1976) indicated that the usefulness of any objective method can be judged either on its correlation with taste panels or on its sensitivity to structural changes. However, decisions on meat product desirability and acceptability can only be determined utilizing consumer-type sensory studies.

If meaningful texture data are to be generated by instrumental means, then knowledge of the sensory textural properties that are indicative of the product to be evaluated is crucial. The diversity of meat and meat products now produced creates an intriguing challenge to identify an appropriate instrumental method for characterizing the textural properties of such meats. In addition, fundamental knowledge about the differences from product to product, including composition, processing and structure, are important in this decision. There are two basic categories of meat products. These are the cooked, intact muscle cuts and processed meat products. From a measurement of texture standpoint, the processed meat products (including restructured meats) can be classified into coarse ground or flaked and finely comminuted processed meats.

Intact meats have been evaluated for various sensory texture-related traits. Harries et al. (1972) evaluated seven quantified sensory factors (resistance, wetness, juiciness, cohesiveness, hardness, overall texture, and chew count) on cooked roast beef texture. They concluded from a factor analysis that the two most significant factors were describable as "toughness-tenderness" and "juiciness," which when combined accounted for 95% of the total sample variation. They further stated that cooked meat was a considerably simpler system than most foods, lacking various characteristics such as hardness, brittleness, gumminess, oiliness, lumpiness and graininess. In contrast to intact muscle cuts,

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processed meats, because of the diversity in manufacturing procedures and non-meat adjuncts, entail a much more extensive list of textural traits in order to fully characterize them.

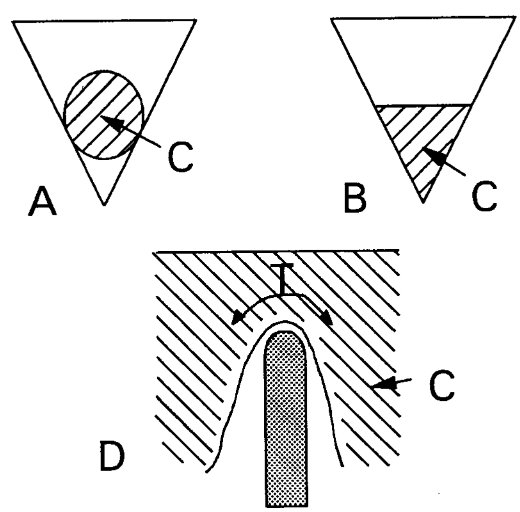
Instrumental texture methods can be classified as either: 1) empirical, 2) imitative, or 3) fundamental. Empirical tests include shear, puncture and extrusion, and although poorly defined, have been found to be significantly correlated with sensory texture (Bourne, 1978). Empirical tests are easier to perform and the instrumentation is generally less expensive to purchase and operate. Imitative tests are those that attempt to mimic the conditions that are imposed on the food during mastication (Bourne, 1978). According to Bourne (1982b), fundamental tests measure well-defined rheological properties. Bourne (1982b) further stated that these types of tests were originally developed by engineers interested in designing stronger materials to withstand the forces imposed on the structures built from these materials. In some cases, this would be in contrast to the goals of a food scientist. As an example, a food scientist may be interested in designing a low-fat processed meat that is softer and less cohesive through the use of non-meat adjuncts. Another difference is that the material scientist normally stops when the test sample has broken into two pieces (Bourne, 1982b). However, a food scientist may consider this initial break as the beginning of the testing which is not complete until the food has been broken down into progressively smaller pieces (Bourne, 1982b). Fundamental texture tests must provide independent measurements of different textural parameters (Hamann, 1987). For most processed meat, this can be accomplished when the specimen is quite homogenous and isotropic, with the latter meaning the specimen has properties independent of orientation (Hamann, 1987).

Characteristics of the ideal objective method would include: simple, fast, high correlation with sensory texture, diagnostic, reproducible results (within samples and from lab to lab), technician-friendly, capable of being interfaced to a computer (control and data acquisition), versatile across all product types, and relatively inexpensive to purchase and operate. Bourne (1982b) stated that the ideal texture measuring apparatus should combine the best features of the fundamental, empirical and imitative methods and eliminate the undesirable features of each of these methods.

Some instruments used to determine meat texture include: 1. Shearing devices; a. L.E.E.-Kramer Shear Press, b. Allo-Kramer Shear, c. Modified, straight-edged and "V" shaped Warner-Bratzler Shear, 2. Penetration devices; a. Armour Tenderometer, b. Christel Texturemeter, c. Slice Tenderness Evaluator, d. U.S. Army Meat Penetrometer; 3. Biting devices; a. Lehmann Dexometer, b. Volodkevich Bite Tenderometer, c. M.I.T. Denture Tenderometer, d. General Foods Texturometer, and 4. Tensile testing instrumentation (Berry, 1983; Campion, et al., 1975; Harris, 1988; Herring, 1974; Szczesniak and Torgeson, 1965; Voisey, 1976). In addition, there is a myriad of other instruments, making it infeasible to cover even briefly in this document. In review of the literature, there are a few key instrumental texture methods that will be further discussed in this paper.

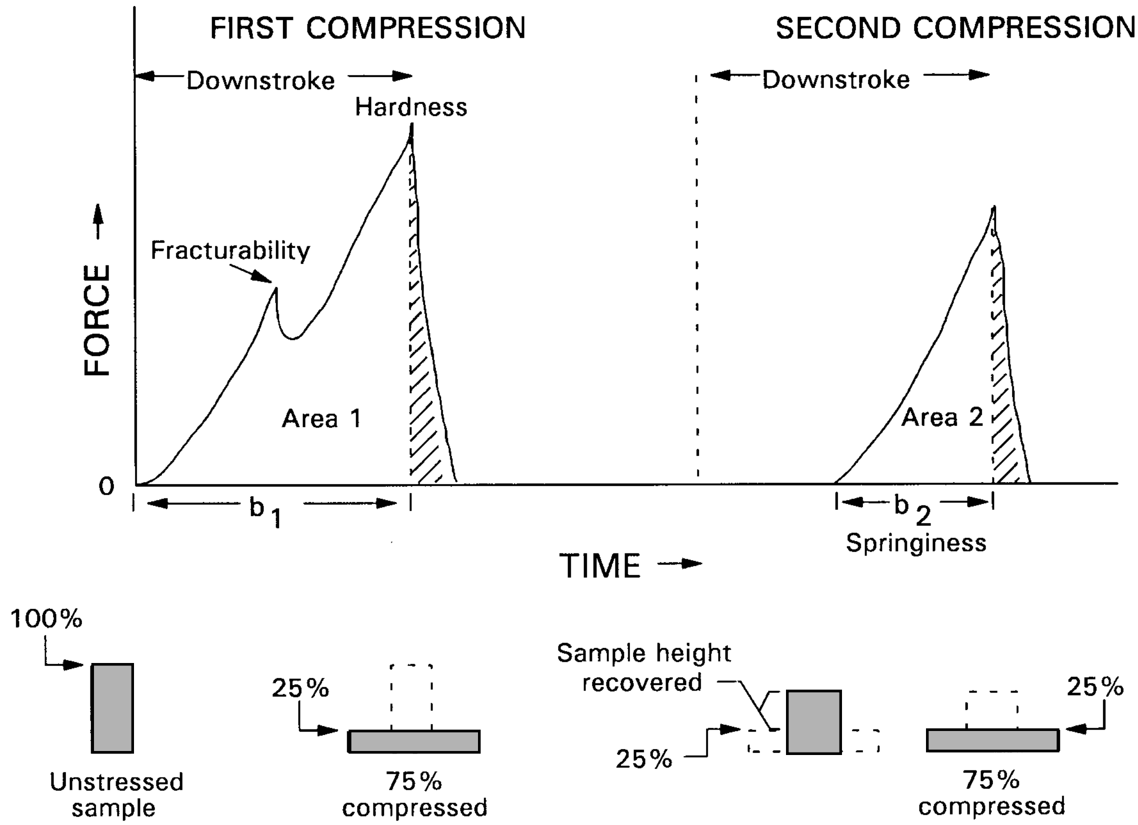
The Warner-Bratzler shear device has been used extensively to evaluate meat texture over the past 60 years. This device provides an empirical test of meat texture. The original Warner-Bratzler shear device was later adapted as an attachment to more sophisticated electronic instrumentation, including the Instron Universal Testing apparatus. When adapting the Warner-Bratzler shear attachment to other instrumentation, it is important to purchase an attachment with the original Warner-Bratzler equipment specifications. Voisey and Larmond (1974) investigated various factors that affect the performance of this device and within their paper reported the original blade and guide specifications. Despite its widespread use, there are some deficiencies in this methodology. Results from numerous studies summarized by Szczesniak and Torgeson (1965) involving beef, pork, turkey or chicken documented correlations between Warner-Bratzler shear and sensory tenderness that ranged from non-significant to very significant. As with other empirical methods, this method has confounding properties that exist during sample testing. Voisey and Larmond (1974) schematically illustrated the physical action of this device on the sample (Fig. 1). Stanley (1976) indicated that a serious drawback with this method was that it combined two properties that may or may not be dependent on each other. These properties were stated as 1) firmness as indicated by the applied force on compression area of the sample, a viscoelastic property of meat; and 2) tenderness as indicated as the maximum applied force, a tensile rupturing property of the mat. The first property is measured transversely to the meat fibers, indicative of compression and the latter along the fiber axis, characteristic of tension (Stanley, 1976).

FIGURE 1



Schematic of Warner-Bratzler shearing action. A, unstressed core sample; B. sample deforms to accommodate available space; C, sample; D, view of blade edge; T, tensile stress.
Adapted from Voisey and Larmond (1974).

FIGURE 2



Schematic of typical Texture Profile Analysis curves using an Instron Universal Testing Machine. Springiness is the base width, b_2, of the second compression. Figure was modified from Bourne (1978) to be more representative of processed meat samples.

Recently, a committee was formed by the American Meat Science Association (AMSA, 1995) to update the publication *Research Guidelines for Cookery, Sensory Evaluation and Instrumental Tenderness Measurements of Fresh Meat.* These guidelines recommend procedures for both intact meats and ground beef. At the international level, recommendations for reference methods to assess meat tenderness also have been reported (Chrystall et al., 1994). A comparison between these two recommendations (AMSA, 1995 and Chrystall et al., 1994, respectively) illustrates some of the differences and similarities: 1) sample configuration - 1.27 cm core vs square sample; 2) shear speed - 200 to 250 mm/min vs 50 to 100 mm/min; 3) blade and guide specifications - must use that manufactured by G-R Electric, Manhattan, KS or milled to exact specifications including "V" shape blade vs 1.2 mm thick blade with a rectangular-shaped hole; 4) shear orientation to muscle fibers - both perpendicular; 5) minimum number of samples - both six; and 6) shear rate important - most likely vs not likely.

The Texture Profile Analysis (TPA) procedure reported by Bourne (1978) as an imitative test has been widely used (Fig. 2). A variety of meat products (ground beef, frankfurters, bolognas, restructured pork) and model gel systems have been characterized using TPA (Claus et al., 1989, Montejano et al., 1985; Small et al., 1995; Sylvia et al., 1994; Todd et al., 1989; Troutt et al., 1992). Bourne (1978) reported that TPA involved compressing a bite size sample to 25% of its original height (75% compression) two times in a reciprocating motion that imitated the action of the jaw. Analyses of force-time curves led to the identification of five measured textural parameters and two calculated parameters (Bourne, 1978). The seven parameters were fracturability, hardness, cohesiveness, adhesiveness, springiness, gumminess and chewiness. Adhesiveness is rarely a reported parameter for meat products and as such will not be discussed further. The remaining parameters reported by Bourne (1978) were defined as follows: 1) Fracturability, the force at the first significant break in the curve, 2) Hardness, the maximum peak force during the first compression, 3) Cohesiveness, the ratio of the positive force area during the second compression to that during the first compression, 4) Springiness, the height that the food recovers during the time between the end of the first compression and the beginning of the second compression, 5) Gumminess, the product of hardness times cohesiveness and 6) Chewiness, the product of hardness times cohesiveness times springiness.

Differences in the definition of calculation of TPA springiness have been reported. Montejano et al. (1985) defined springiness as the proportion of the compression distance recovered between the first and second compressions. Claus et al. (1989) expressed springiness as a percentage as follows: $b_2/b_1 \times 100$ (b_2, base width of the second sequential compression; b_1, base width of the first compression). Although not formally evaluated, springiness measured as b_2/b_1 and $b_2/b_1 \times 100$ measured in my laboratory appeared to be more sensitive to detecting differences between various treatments than b_2 alone.

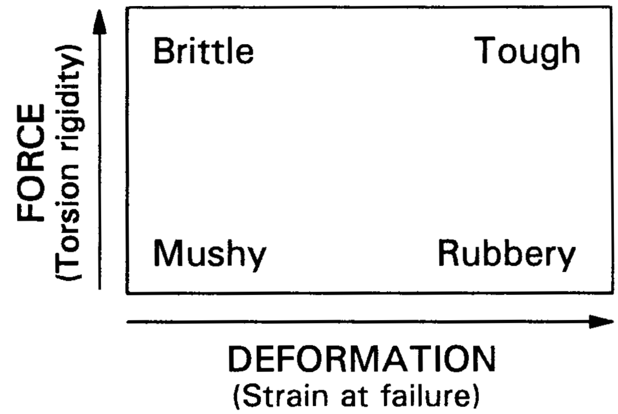
Bourne (1978) indicated that for the General Foods Texturometer the test sample was a small flat-faced cylinder, usually a cube approximately 1.2 cm along each side. Sample configuration for meats characterized using an Instron varied from strips for ground beef (1.0 mm x 3.0 m x patty height; Troutt et al., 1992) to cores for finely comminuted sausages (19 mm diameter x 19 mm height, 22 mm diameter x 10 mm height and 25 mm x 19 mm height; Claus et al., 1989; Small et al., 1995; Stech et al., 1988). Some differences in the core size may have been a result of limitations relative to the diameter of the casing used to manufacture the sausages.

A significant challenge in using TPA for different meat products is related to establishing an appropriate level of compression for that product. Compression levels of 70% have been reported for ground beef (Troutt et al., 1992), 50% and 75% for frankfurters (Singh et al., 1985; Small et al., 1995), 25% and 75% for bologna (Claus et al., 1989), and 75% for restructured pork (Todd et al., 1989). Depending upon the product analyzed, some level between 25% and 75% may be more appropriate. The reason is that if the sample is compressed too much, there will be minimal structural integrity remaining for the sample to recover and hence provide measures of cohesiveness, springiness, gumminess and chewiness. On the other hand, if the sample is under-compressed there may not be any significant fracturability and an uncharacteristically low hardness. In addition, such an under-compression would appear to measure an extremely cohesive and springy product. Ideally, the correct compression would be somewhere in between, resulting in some degree of sample structural failure (fracture) without completely destroying the sample.

Correlations between TPA and sensory results were reported in a study utilizing 8 protein gels made from beef, pork, turkey, two surimi sources, and three egg-white treatments (Montejano et al., 1985) and a study characterizing bolognas manufactured to contain 30% fat - 10% added water to 5% fat - 35% added water (Claus et al., 1989). Correlations were 0.74 and 0.79 for TPA hardness and sensory firmness, 0.66 and -0.03 for TPA springiness and sensory springiness, and 0.81 and 0.42 for TPA cohesiveness and sensory cohesiveness. TPA fracturability was highly correlated (0.86 and 0.84, respectively) with sensory cohesiveness and firmness, respectively (Claus et al., 1989). The correlation between TPA chewiness and sensory chewiness was 0.75 (Montejano et al., 1985).

Torsion testing is a fundamental method that can be used to evaluate finely comminuted sausages and various protein gel systems. The torsion or twisting test basically involves

FIGURE 3



Texture map adapted from Lanier (1986) and Hamann (1987).

mounting a dumbbell-shaped sample on a torsion device such as a Torsion Gelometer (Gel Consultants, Inc., Raleigh, NC) and twisting the specimen at a specific rate (e.g. 2.5 rpm) until structural failure occurs (Kim et al., 1993). Fig. 3 illustrates the relationship between force (torsion rigidity) and deformation (strain at failure). Depending upon the results from this analysis, the meat product can be described by the four sensory descriptors of brittle, mushy, tough and rubbery.

Bourne (1978) indicated that fundamental tests are generally slow to perform and do not correlate as well as do empirical methods. However, Montejano et al. (1985) reported significant correlations of torsion and sensory textural traits (shear stress with springiness, 0.62; firmness, 0.72; cohesiveness, 0.62; chewiness, 0.69; and shear strain with springiness, 0.83; firmness, 0.80; cohesiveness, 0.87; chewiness, 0.79). Also, in comparison to other instrumental tests, the torsion test does a better job of producing two understandable and independently-measured failure property descriptors than puncture force and punch deformation because changes in specimen shape and size are minor (Hamann and Lanier, 1986).

In conclusion, advances in improving instrumental methods of measuring meat texture have been made. However, despite the wealth of information on the factors that affect meat texture and on instrumental methods to assess texture, there is not a single method available to appropriately evaluate this trait for all meat products. Nevertheless, by continuing to document the most highly recommended current procedures for objective determination of meat texture, hopefully scientists will adopt these methods in order to facilitate the direct comparison of results from various institutions.

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TEXTURE SUMMARY

Dr. Jim Claus from VPI & SU and a member of the AMSA Committee on Research Guidelines for Cookery, Sensory Evaluation and Instrumental Tenderness of Fresh Meat set the stage for reciprocation by illustrating advantages and limitations of various texture measurements. Examples of various empirical, imitative and fundamental texture procedures were compared.

Jim created the atmosphere for reciprocation by identifying major differences in texture-measuring protocol between the new American Meat Science Association (AMSA) and new Organization for Economic Cooperation and Development (OECD) publications for researchers. Questions posed for later discussion included, "Should one international set of standards be developed for measurement of texture?" and "If so, what criteria should be included in the standards?"

During the discussion, considerable interaction occurred regarding the major differences in procedures between the AMSA and OECD recommendations. Those major differences are:

- Sample configuration: AMSA=1.27 cm core; OECD=square sample
- Shear force speed: AMSA=200 to 250 mm/min; OECD=50 to 100 mm/min
- Cookery of steaks: AMSA=broiling; OECD=water bath cooking in bags

It was mentioned that part of the reason for taking square samples exists in the ability to more accurately determine fiber orientation. However, the ensuing discussion suggested that acceptable fiber orientation could also be achieved by coring.

The general consensus was that shearing samples perpendicular to the longitudinal orientation of the fibers is appropriate - greater repeatability can be attained. However, the errors associated with slight deviations in shearing perpendicular to fiber direction may be small compared to not fully sampling to encompass the entire variation in tenderness in the muscle. Also, collectively, not adhering to other factors important in determining shear force may result in serious errors.

Attendees pointed out that torsion testing in combination with texture profile analysis provides useful information with processed meats, even in low-fat products. With low-fat meat products, the influence of protein on surface "skin" formation in such products as frankfurters becomes very important. Use of penetration (probe) devices may be necessary to accurately assess the role of "skin" on texture. Several institutions mentioned that multi-bladed shear measurements should be considered with beef patties.

Reciprocation occurred on calibration and verification of the texture-measuring equipment. It was mentioned that sharpness of blades can vary and provide different results. The necessity exists for a good reference material for calibrating and monitoring test equipment at different locations.

The considerable difference in meat cookery for texture evaluation was also a subject of discussion. Given consideration was the age-old question of "Do we cook to simulate consumer methods or rather use cooking systems that may reduce some product variability in texture?" Those defending water-bath cooking mentioned that tradition had played a role in its continued use. It was mentioned that water-bath cooking has even been used with "patty" products, but this approach to cooking may be too different from consumer cookery to fully answer all questions regarding texture. Longer time cooking would also decrease the impact of connective tissue on texture.

Additional discussion occurred on the importance of instrumental texture measurements - can we have them without trained sensory and consumer evaluation? Does sensory direct the instrumental approaches to use or vice-versa? While full consensus wasn't achieved, many felt that if consumer-perceived problems are of utmost importance, then sensory may need to direct the instrumental approaches required for texture evaluation. When the focus may be on the effect of formulation changes or ingredient substitution, instrumental approaches may provide more rapid and economical answers.

These questions, many yet without answers, necessitate further research on objective texture methods. The two new research guidelines will provide much needed standardization of methodology and hopefully, in the future, will lead to the development and adoption of international guidelines.