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TEXTURE ANALYSIS APPLICATION OVERVIEW

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Texture is a very important parameter in the total quality of meat and meat products (i.e. whole tissue and processed meats). For the consumer's acceptability of meat, tenderness is a crucial property. As whole tissue meat is a natural product it possesses inherent variability due to many factors. As a sample for testing this presents a common problem to assess the texture repeatably.

Processed meats have three general types: deli-styles (for example turkey, bologna), that are sliced, formed meats (meat balls, meat patties, chicken patties, chicken nuggets) and sausage-style meats which are usually tubular shaped. Processed meats are often investigated to assess, for instance, ideal combinations of ingredients, evaluate contribution of processing methods/times and highlight quality inconsistencies. The measurement issues are however different for each type of processed meat. Deli-style meats need to balance the binders and texturising ingredients to obtain perfect firmness, cohesiveness and low adhesiveness (so that they can be cut) and the correct springiness and resilience to match consumer expectations. Formed meats need to balance moderate firmness (as too much muscle meat identity is not good in a patty) with strong cohesion (since these products are usually handled roughly but must remain whole. Many formed meats are often breaded so crispness is a major textural attribute.

Several meat products are generally more uniform in texture by way of the processing involved in their preparation and as such it is usually easier to find a successful repeatable method for the assessment of their overall texture. The following present a review of some of the types of methods available for the assessment of meat and meat products with some more recent approaches to improve on the repeatability of these quantitative assessments.

*The **TA.XTplus** Texture Analyser*

*The **TA.HDplus** Texture Analyser – required for high force texture analysis*

STANDARD MEAT TESTING METHODS & ANALYSIS TECHNIQUES

The "Standard" Approach

Despite many efforts over the years, there is still little consensus regarding methods of measuring the physical characteristics of meat and meat products. Many methods have been published in the scientific literature but only one procedure has been agreed upon internationally, and then only for beef (Boccard et al, 1981) and this does not appear to have been universally accepted. Standardisation of methods is essential if investigations carried out by different groups are to be directly comparable. Thus some agreement should be made regarding methods of measuring physical quality characteristics in meat and meat products. The lack of standard measurement is in contrast to accepted methods of measuring the chemical components of meat and meat products.

The techniques used to evaluate physical characteristics could be applied for at least three different reasons:

1: As a quality assurance (QA) tool, within a processing operation

2: As an assessment of the effectiveness of production and processing treatments where there may be an interest in being able to compare results between laboratories or countries

3: As a research tool, in fundamental structural studies of muscle and meat.

In the first case, a common methodology needs only to be appropriate for the plant or group of plants being controlled by specific QA programmes. The methods used should measure the desired characteristics necessary to monitor the process, but need not be comparable with other laboratories, where different criteria may be important. Where international comparison is important it is essential that methodologies be standardised. This would include all aspects of the testing procedure and this is an area of which the reference methods are primarily directed.

In contrast, where direct measurements are being made of the physical properties of meat as a function of structural (chemical or physical) changes, the experimental methodologies should not be constrained by reference methods. Instead researchers are encouraged to develop and use methodologies that enhance the precision and accuracy of testing methods and lead to an understanding of the basic mechanisms. It is likely that new understanding will lead eventually to methods that more closely predict consumer assessment of meat characteristics. The **TA.XT*plus*** and **TA.HD*plus*** texture analysers provide the flexibility of testing principles (e.g. compression, penetration, tension, extrusion, etc.) and the endless option of probes and fixtures for texture analysis. Stable Micro Systems itself is an expert in the field of mechanical, electronic and software development for texture analysis which provide leading solutions for this field of testing and research.

The Basis of Test Method Design

Fresh or cooked meat treatments to achieve sensory tenderness are constantly evaluated. Because these treatments usually directly affect the muscle fibres, tests that measure some aspects of fibre characteristics are central to research efforts to achieve simple, yet accurate, ways to evaluate the eating quality of meat. If the first assessment of meat texture characteristics by a consumer is to cut or bite through the fibres, a logical test approach would be to measure the force to cut or break the fibres to provide an indication of what the consumer might perceive. The biting action is used as a basis of many devices designed to provide a measure that will closely relate to human assessment. The most common biting or shearing system for the assessment of meat and meat products is the Warner-Bratzler shear blade – of which one version is shown in *Figure 1*(overleaf), as supplied by Stable Micro Systems. This fixture is an empirical technique developed approximately 70 years ago and employed by quality control/assurance personnel and meat researchers and remains as the main reference in parallel with sensory determinations for the assessment of raw or cooked meat.

Meat Products – Reformed Products: Sausage Shearing using Warner-Bratzler

Factors that affect the results of Warner Bratzler shear tests are: uniformity of sample size, direction of muscle fibres, presence of connective tissue and fat deposits, sample temperature, and speed of shearing.

Figure 2 shows typical texture analysis curves comparing a shearing test on two samples of commercially available sausages: one sample is a German frankfurter style sausage (finely comminuted) whilst the other is a Spanish-style pork sausage known as a 'Chorizo' (coarsely ground meat product). Both were held at a temperature of 5°C prior to testing in their vacuum-sealed packaging. A few moments before testing, the packaging was removed and the sausages were placed individually under a Warner-Bratzler blade in a central position to the triangular inset. This blade was previously attached to a 5kg load cell and positioned carefully within the slotted base insert, taking care to adjust the blade position to avoid frictional effects with the blade guide slot when testing. A cutting/shearing test was then performed. This test represents a crude method with little sample preparation which lends itself ideally to quick quality determination.

The microstructure of cooked meat emulsion, such as sausage products, may be influenced by the processing conditions, particularly cooking, and its composition, i.e. the type of meat protein, fat-protein ratio, salt level, moisture, degree of comminution and filler content.

The results (as shown in *Table 1*) indicate that Chorizos required the larger force and total energy (work) to shear. The shearing of muscle fibres and connective tissue requires much larger energy than the breaking of ground or finely comminuted products as is such for frankfurters.

The "Standard" Warner Bratzler Blade

Standard Warner-Bratzler shear force involves measurement of cooked meat tenderness using a Warner-Bratzler blade (see *Figure 3*) that adheres to the following specifications: **a)** shearing blade thickness of 1.016mm; **b)** a V-shaped cutting blade with a 60 degree angle; **c)** the cutting edge bevelled to a half-round; **d)** the corner of the V should be rounded to a quarter-round of a 2.363 mm diameter circle; **e)** the spacers providing the gap for the cutting blade to slide through should be 1.245mm thick;

Figure 1: *A Stable Micro Systems Warner-Bratzler blade (stainless steel, 70mm wide, 90mm high, 3.2mm thick)*

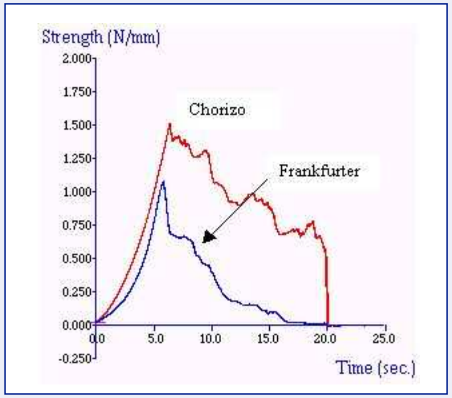

Figure 2: *Typical texture analysis curves of sausage-style products using a Warner-Bratzler blade*

Sample	Max. Shearing Force (N/mm) (± S.D.)	Total Work of Shear (N/mm s) (± S.D.)
Frankfurter	1.26 ± 0.11	6.5 ± 0.5
Chorizo	1.67 ± 0.14	17.0 ± 1.8

Table 1: *Results of sausage shearing tests using the TA.XTplus Texture Analyser and Warner-Bratzler blade*

f) the cooked meat samples should be round cores 1.27 cm in diameter removed parallel to the longitudinal orientation of the muscle fibres; and **g)** the cores should be sheared once at the centre, perpendicular to the fibres to avoid hardening that occurs toward the surface of the cooked sample (Bratzler, 1932, 1949; AMSA, 1995; Wheeler *et al*, 1995). The maximum force is termed the Warner-Bratzler shear force. It is considered that shear tests conducted with modifications to these specifications (e.g. square notch in the blade, square meat samples, straight cutting blade, or blade edge not bevelled) should not be referred to as Warner-Bratzler shear force.

The basic concept and design of the Warner-Bratzler shear device have however been subject to modification and improvement over the years. Yet, the familiar blade, with its triangular notch in the middle, remains one of the most widely used devices to provide measurements of meat texture quality. The width of the blades and the position of the triangle; the speed of the test; the shape, mass, and orientation of the test sample are of course important to interpretation of the results of shear tests but as is always found with "standard" methods and attachments there will always be reasons for modification of the specification of a test fixture and groups of researchers who prefer to move away from a standard to a method that suits their particular research purpose.

One such group is responsible for the development of a new variant of the original Warner-Bratzler blade.

The "European Standard" Warner-Bratzler blade

As a spin-off of a workshop on pork quality, held in Helsinki in 1992, a group of scientists with many years of experience in the field of meat quality assessment convened in 1993 for the first time, and subsequently in 1994 and 1995 in Kulmbach at the German Federal Centre for Meat Research to develop internationally accepted reference methods. In the Autumn of 1997 these methods (which include the following method for tenderness) were brought into their final form at the Meat Industry Research Institute of New Zealand.

Although Warner-Bratzler devices and sample configuration are extremely variable, the recommended equipment according to this "European" network is as follows. The blade should be 1.2mm thick with a rectangular hole 11mm wide and at least 15mm high. The hole should have square smooth edges and the blade should be drawn or be pushed at 50-100mm/min between side plates positioned to provide a minimum gap between blade and plates (see *Figure 4*). The sample should be cut from a block of cooked meat and taken to avoid damage. Sample strips should be cut with a 100mm2 (10mm x 10mm) cross-section with the fibre direction parallel to a long dimension of at least 30mm. The sample should be sheared at right angles to the fibre axis. The parameters to be measured from the force deformation curve are the peak force (the maximum recorded) and the total energy. Initial yield may be useful in some instances but will not always be apparent.

***Figure 3:** "Standard" Warner Bratzler shear force test*

***Figure 4:** "European" Warner-Bratzler "Standard" blade for Meat testing*

Meat Products – Reformed Products: Canned Ham – Multiple Shearing

The Kramer shear cell (see *Figure 5*) is a multi-bladed device. The sample to be sheared is often variable in configuration or structure. The result is an average of the forces required to cut through the sample of variable geometry. This device would lend itself ideally to reformed products such as tinned hams, meat pieces (such as fillet strips or chunks) and shaped (and usually breaded) poultry products e.g. chicken nuggets.

Figure 6 shows typical texture analysis curves comparing a multiple shearing test on two samples of commercially available canned ham products: one sample was purchased as a 'cooked lean formed ham', which maintained much of its initial meat fibre integrity, whilst the other was a 'premium reformed ham', consisting mainly of meat chunks bound together. Both were removed from their cans, covered and held at a temperature of 5°C prior to testing. Samples were cut to optimum dimensions and placed separately and centrally into the Kramer Shear cell. The set of 5 blades were attached to a 100kg load cell and their position had been adjusted to avoid frictional effects with the cell when moving down into it. A multiple cutting/shearing test was then performed on a TA.HD*plus* texture analyser.

The results (see *Table 2*) show that the formed ham required the largest force to shear compared to the preformed 'mainly chunks' ham. This is probably due to the loss of meat integrity of the preformed sample and indicates that the force to shear through the meat fibres of the formed sample is greater than to shear and separate a sample consisting of bound together meat chunks.

Figure 5: *A Kramer shear cell is typically suited to meat pieces or coated meat products*

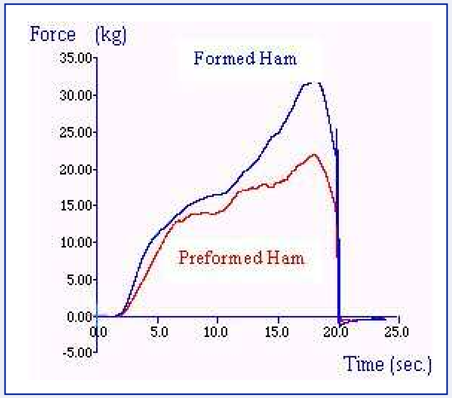

Figure 6: *Typical texture analysis curves of ham products using a Kramer shear cell*

Sample	Max. Shear Force (± S.D.) (kg)
Formed Ham	29.7 ± 2.2
Preformed Ham	22.5 ± 1.6

Table 2: *Results of ham shearing tests using the TA.XT2i Texture Analyser and Kramer shear cell*

Chicken Tenderness – Multiple Shearing

Similar tests, as for those described for ham, can be used to analyse chicken tenderness. *Figure 7* shows the resulting curves of two fresh chicken types, tested using the Kramer shear cell. Clearly, chicken type A requires much more force to shear than does chicken type B, and is therefore tougher.

With the results, processors of chicken can determine for instance, the quality of the meat. Poor quality feed and certain slaughter conditions can produce lower quality meat. This allows the processor to correlate texture with feed type etc. and so attempt to control, amongst others, future rearing, feeding, or slaughter conditions.

Most innovative poultry products, e.g. chicken nuggets, are now coated in a number of layers to provide flavour and texture as well as to add value. Before the product can be coated it has to be formed correctly to give good shape and integrity as well as provide adhesion for the coating. Overuse of cryogens during the forming process can damage meat definition resulting in textural deficiencies. Other factors such as cooking method, duration of cooking and meat choice extend the range of potential texture-affecting concerns. In the processing of meat patties, nuggets and chicken burgers, the meat must be mechanically manipulated to produce a formed product. The degree of physical manipulation is selected depending upon the overall mouthfeel, i.e. whether a smooth uniform texture is required or a coarse texture.

Whilst the Kramer shear cell allows the testing of a larger sample size and therefore can have the advantage of testing using an averaging effect which is advantageous for the repeatable testing of highly non-uniform products, the drawback is often that this type of test commonly requires a high force load cell, e.g. 500kg, and therefore lends itself to a TA.HD*plus* application.

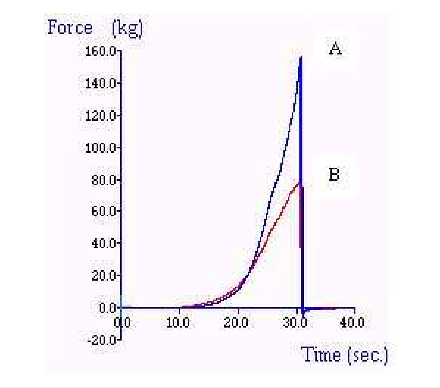

Figure 7: *Typical texture analysis curves of chicken products using a Kramer shear cell*

Recent Shearing Variations to Meat Testing Methods & Analysis Techniques

The University of Arkansas has developed a new test method for quantifying poultry firmness. The method was presented recently in the *Journal of Food Science* and presents a new shearing method for the determination of poultry meat tenderness and uses a razor blade or craft knife type attachment to perform a cutting/shearing test. It is claimed to exhibit a higher correlation to sensory attributes than the Kramer Shear method. This new method not only has a higher sensory predictive value, but also requires shorter sample preparation time than the Kramer shear test or Warner-Bratzler method because it is conducted on intact fillets and measured forces are substantially lower than those produced with a Kramer Shear test, thereby allowing testing on a TA.XT*plus* Texture Analyser. When performing cutting/shearing tests the consistent sharpness of the blade is always a consideration or cause for concern. The benefit of performing tests using a readily available craft knife blade (such as that shown in *Figure 8*) is that the blade can be removed and replaced after each test or an agreed number of tests, assuring edge sharpness and therefore increasing the repeatability of the results.

Razor blade shear energy and shear force were determined on intact fillets with an average height of 20mm at predetermined locations on the fillet. Using the Texture Analyser accommodating a 5kg load cell the razor blade (height 24mm; width 8mm) was set to penetrate to a depth of 20mm at a test speed of 10mm/s.

The razor blade shear force is calculated as the maximum force recorded during the test, whereas the razor blade shear energy is calculated as the area under the force deformation curve from the beginning to the end of the test.

Figure 8: *Razor blade shear force can be assessed using a readily available craft knife attached to a TA.XTplus Texture Analyser*

Meat Products – Paté & Pastes: Measuring Paté Firmness

More and more often paté is being eaten as a snack spread onto toast, bread or crackers. It is usually made by pre-cooking liver and other meats, mixing them with other ingredients, seasoning and then filling into moulds or casings. There are many variations as a result of using different ingredients and nowadays low fat pate is also an option.

In meat products, fat contributes to flavour, texture and mouthfeel, therefore fat reduction by itself can significantly affect the acceptability of the product. One of the major factors in lowering acceptability is increasing the toughness of the meat product. Several approaches to reduce the fat content without substantially affecting the texture have been explored. They include the use of soy proteins and the use of various gums such as xanthan, carrageenans, locust bean gum, and methylcellulose.

The preparation of low-fat meat emulsions presents a number of difficulties in that fat has a considerable influence on the sensory characteristics and texture of the product. A variety of technological procedures such as massaging, pre-blending and so on, and likewise the incorporation of various non-meat ingredients, have been tried to offset the effect of reduced fat levels and help to obtain acceptable low-fat products. The quality attributes of low-fat products depend on the matrix formed, which in turn varies according to both fat and protein contents. However, the effects produced in meat products by variation of fat and protein contents are influenced in turn by a number of factors, an important group of which are connected with processing. Indeed, processing conditions are largely responsible for many aspects of final quality in meat products. Textural characteristics are closely associated with the heating regime, so that advantage may be taken of such factors as heating rate and/or profile, final temperature, procedure used, etc. to improve the manufacturing technology, alter composition and enhance sensory characteristics.

Figure 9 shows a typical texture analysis curve comparing a penetration test on two samples of commercially available smooth pork liver pate: one sample is a full fat formulation whilst the other is its reduced fat counterpart. A 10mm cylinder probe was used to perform a penetration test and indicated that the reduced fat product requires a larger force to penetrate it and therefore has a firmer consistency than the full fat version. A variety of penetration probes are available for this type of test, as shown in *Figure 10*. The testing of a more coarsely chopped pate or paste introduces more heterogeneity to the product and the repeatability of a single penetration test can be compromised. The use of a Multiple Puncture Probe (shown in *Figure 11*) which penetrates the sample in several regions serves to create an averaging effect and is therefore usually more repeatable.

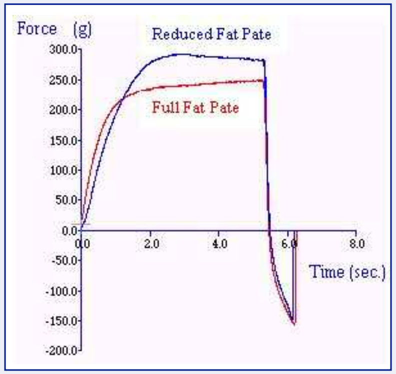

Figure 9: *Typical texture analysis penetration curve comparing full- and low-fat pate*

Figure 10: *A variety of penetration probes available from Stable Micro Systems*

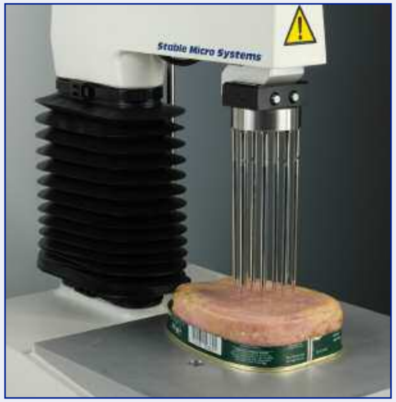

Figure 11: *Multiple Puncture Probe performing a test on tinned ham*

Sample	Maximum Force (“Firmness”) (± S.D.) (g)
Full fat pate	227.5 ± 11.2
Low fat pate	300.9 ± 5.1

Table 3: *Results of pate penetration tests using the TA.XTplus Texture Analyser*

OTHER GENERAL MEAT TESTING METHODS

Volodkevich Biting

Other testing techniques have also being used in the industry. For instance, a smaller shearing test using Volodkevich Bite Jaws (as shown in *Figure 12*) has been used where samples can be prepared to precise cross-sectional dimensions (normally approx. 10mm x 10mm). The meat piece is rested between the 'jaws' of the rig and the sample shearing is performed by an upper device which is similar in geometry to an incisor tooth. The limitation of the cross-section of the sample and the sometimes cumbersome holding of the sample prior to contact with the upper jaw has decreased the popularity of this method in the last decade.

Figure 12: *Volodkevich Bite Jaws – suited to the testing of small meat cross-sections*

TPA (Texture Profile Analysis)

In certain circumstances TPA (Texture Profile Analysis) compression may be a suitable technique. When using TPA the general rule is that this test is meant to be a high deformation test and therefore a high % strain is advised, for instance 80%. However, TPA has been found to be useful at differentiating sliced processed meats made with different binders and carrageenans at 30% strain. A typical TPA curve is shown in *Figure 13.*

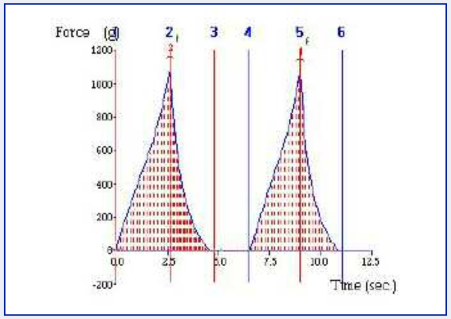

Figure 13: *Typical TPA graph*

Tensile Testing

Another method of interest in meat research is the area of tensile strength. Many researchers over the years have been able to measure not only this parameter but also the time scale of the 'onset of rigor'. By performing a 'Hold Until Time' test and holding a specific clamping force on the sample (using Tensile Grips as shown in *Figure 14*), when contraction occurs, the TA.XT*plus* is forced to move to maintain the specific force. Tracking of change of distance, over a certain time period, will indicate any contraction or extension periods during the test.

The tensile test is best suited for structural investigations rather than to predict sensory evaluation of tenderness. It is a useful test in conjunction with other methods. The test can be carried out on raw or cooked meat but if conducted on cooked meat the cooking procedure (time and temperature) can have a large influence on the sample force deformation and needs to be strictly defined. The standard slices of the tensile test samples are cut using a template (see *Figure 15*) to define dimension and shape. If smaller samples are required because of physical restrictions imposed by muscle size and shape then the proportions of 4:1:0.5 for length:width:thickness should be maintained.

Specimens should be subjected to extension of 50mm/min and a force deformation curve to complete rupture should be obtained from which the total energy to fracture, breaking stress and breaking strain can be determined. Because of variability a minimum of eight to ten specimens should be tested and larger amounts of connective tissue in the samples tested cause high variability.

Results are largely affected by sample size and strain rate, but the latter effect is small. Problems with gripping the samples are a major cause of measurement failure, especially with raw meat. Cyanoacrylate adhesives or freezing grips can be employed although the sample will normally be gripped with pneumatic clamps (see *Figure 16*) at pressures sufficient to maintain a firm grip without obvious slippage, yet minimising specimen damage.

Figure 14: *Typical grips for tensile testing*

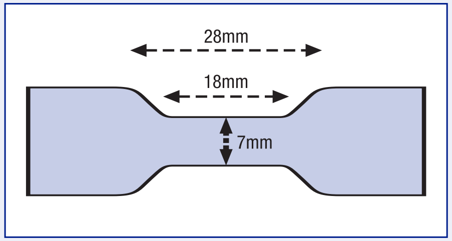

Figure 15: *Shape of template for tensile test*

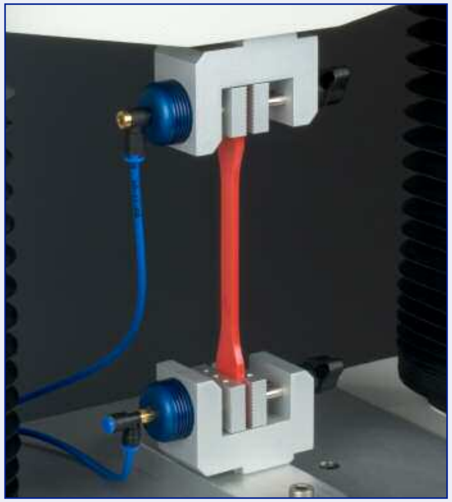

Figure 16: *Measurement of tensile properties of meat – samples clamped via Pneumatic Grips*

Stress Relaxation Technique

A biomechanical study has been conducted at Texas A&M University to characterise mechanical properties of post rigor bovine *m. longissimus thoracis et lumborum* muscles. Linear viscoelastic properties were measured using a standard stress-relaxation technique at 3% strain. A boundary value problem that partially mimicked a simplified model of a first chew cycle of the human masticatory process was solved, and stiffness and total energy dissipated were calculated and correlated to tenderness traits, as evaluated by a descriptive attribute sensory panel. Stiffness and total energy dissipated were highly correlated to overall tenderness ($R = 0.86$ and $R = 0.91$), and a model to predict tenderness using total energy dissipated was successfully developed. This method presents a more fundamental approach to texture analysis and highlights that the range of tests and techniques available using the TA.XT*plus* and TA.HD*plus* Texture Analyser stretches from simple and empirical to more scientific and sophisticated.

Meat Sample Preparation

All of the methodologies described here will provide 'tenderness' measurements. Each method has its advantages and limitations. As with all test methods that are developed, the repeatability of the method relies heavily on the repeatability of the sample preparation, which for a natural product such as meat is often difficult due to its inherent variability. In describing the methods there is the premise that measurement procedures should always be well defined and accurately reported regardless of which methodology is being used – these include, for example, sampling location and dimension, storage, cooking and pre-testing details.

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For more detailed information of texture analyser settings, special calculations, specific sample preparation procedures and data analysis techniques on any of the above mentioned tests, please contact Stable Micro Systems: app.support@stablemicrosystems.com

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