Measurement of Meat Texture

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While suitable systems are available for assessing texture attributes of meat products, there is still a need for revised procedures, modifications and new approaches. The increased production and consumption of processed meat and restructured meat products necessitates the development of new approaches to measure meat texture, since these products often possess textural properties that are more complex than intact muscle products. Thus, the area of meat texture assessment is a fertile field of research. The literature, in terms of development, is very recent. Some of the procedures employed do not always provide the reliability and consistency of desired results. This problem is partially due to an incomplete basic knowledge of the underlying principles influencing meat texture. This paper will deal only with instrumental and sensory approaches to measuring cooked meat texture, with the subject of raw meat texture measurement being the subject of a possible future round table discussion.

Instrumental Methods

Szczesniak and Torgeson (1966) published an extensive review of the various methods of measuring meat texture at that time. Since then, other instrumental systems have been developed, including various modifications to the Instron Universal Testing Machine. The more recent developments in the field of instrumentation for food texture were published by Voisey and deMan (1976). There are several excellent review papers dealing with objective texture measurements in foods that should be reviewed by scientists involved in studies of meat texture (Szczesniak and Torgeson, 1966; Mohsenin, 1970; Voisey, 1971; Stanley, 1976; and Voisey, 1976 a,b).

Voisey and Larmond (1974) reported on extensive experimentation examining the factors affecting the performance of the Warner-Bratzler shear machine, an apparatus used widely for meat tenderness studies. They concluded that shearing rate, blade thickness, clearance between blade and slot, shape of the hole in the blade and condition of the hole edges are all factors that must be controlled in order to obtain reliable data. It was further noted in this study that the Warner-Bratzler shear is not measuring true shear. Actually, firmness, as indicated by the applied force and compressed area of the sample, and tensile stresses are involved. The latter is noticed when the edges of the sample are bent over the shearing blade before any actual shearing occurs. It may be important to determine the degree of sample deformation and type of tensile stresses in assessing the complete picture in meat texture during shearing. Voisey (1976c) indicated that studies using the Warner-Bratzler shear should attempt to assess such textural parameters as: initial yield force (an indication of tensile rupture); sample area at rupture (indication of the compression required to initiate rupture); slope of the force (time-deformation in the second compression phase — a measure of firmness); force per unit sample area at peak; force per unit length of blade cutting the sample when instant peak force is measured; ratio of the sample area at a selected point to the original point, and forces and areas in the zone following the peak. Kastner and Henricksen (1969) pointed out the importance of obtaining uniform meat cores for shearing and provided details of a mechanical device for coring which was superior to hand coring.

The Instron Universal Testing Machine has been used recently as a texture-testing apparatus for a variety of meat products. This machine has been used for intact muscle (Hayward et al., 1980; Huang et al., 1977; Stanley et al., 1971), frankfurters (Prusa et al., 1982), processed meats (Gillet et al., 1978) and ground beef (Cross et al., 1978b; Ockerman et al., 1981). Other machines that have been used for meat texture studies include the L.E.E. Kramer Shear, Allo-Kramer Shear, Slice Tenderness Evaluator, M.I.T. Denture Tenderometer and Ottawa Texture Measuring System (Szczesniak, 1973).

Instrumental Test Properties

Various mechanical properties of texture can be determined by instrumental methods. Shear is a property often measured in food products. However, according to Voisey and deMan (1976), since foods are relatively soft, they deform with small forces. Other factors besides shear certainly are involved in mastication, thus it is probably important in many meat products to consider the other mechanical forces that are involved. Generally shear, tension and compression are applied in combination by instruments and in chewing. Quite often the lack of rigidity allows the sample to deform and these shape changes permit tensile and compression stresses in combination with shear. It has been noted in stress-strain curves associated with shear tests (Stanley et al, 1971) that after fibers with the lowest break elongation begin to fracture, the breaking is accelerated as the increasing load is spread over the remaining fibers. The friction that may be encountered in shearing can be often eliminated by reducing the thickness of the blade (Voisey, 1976a).

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Table 1. Guide to Using Sensory Panels[a]

Requirement	*Type of panel*		
	Preference acceptance	*Discriminative*	*Descriptive*
To determine consumer likes and dislikes	+	−	−
To create a new product with no prototype	+	−	+
To match a prototype or standard	−	+	+
To improve a product	+	+	+
To evaluate effects of packaging, storage, change in process, change in ingredient	−	+	+
To define specifications	−	−	+
Quality control	−	+	+
To measure sensitivity	−	+	−

Panel method	*Function*	*Recommended panel size*
Preference/Acceptance	*Evaluate consumer opinions*	
Hedonic (verbal or facial)	rate samples individually for degree of acceptability	80-120 nontrained preferred, at least 30 for rough product screening
FACT (Food Action)	rate samples individually on an action scale	
Paired comparison (hedonic)	select preferred sample from two samples	
Ranking (hedonic)	compare several samples for degree of acceptability	
Discriminative	Determine whether differences exist among samples	
Threshold	determine human sensitivity to specific characteristics	nontrained, as needed
Differences	detect differences among samples	
Degree of difference or scalar difference	rate degree of difference between sample and standard	5-10 trained, or 8-25 semitrained
Paired comparison	detect difference between two samples	
Triangle	detect difference between two samples by separating odd sample from two identical samples	5-10 trained, 8-25 semitrained, 80+ nontrained
Duo-trio	detect difference between two samples by matching one with a standard	
Other variations		
Descriptive	*Evaluate the product in terms of specific characteristics*	
Ranking	compare several samples for intensity of specified characteristics	5-10 trained, 8-25 semitrained, 80+ nontrained
Rating	evaluate individual samples for intensity of specific characteristics	5-10 trained
Profiling	verbal description of product in combination with rating scales for some characteristics	4-6 highly trained

[a]From Abbott (1973)

Table 2. Texture Profile Characteristics and Definitions for Restructured Beef Steaks

I. Visual: Cut steak should be visually evaluated for:
   A. *Distortion:*
      1. Macro-The degree to which overall sample is uneven or warped (as viewed through a frosted glass).
      2. Micro-The degree to which cooked surfaces look uneven or rough.
   B. *Fibrousness:* Degree to which sample resembles steak. (Lack of disruption of components, fibers appear present in muscle arrangement).

II. Partial Compression: Place warm 1" square cube in mouth, and using molars against cooked surfaces, press lightly 4-5 times, wait a count of 2 for each press and evaluate for:
   A. *Springiness:* The perceived degree and speed with which sample returns to original height and thickness.

III. First Bite: Take fresh 1" square, place in mouth using molars as for partial compression and evaluate for:
   A. *Hardness:* Amount of force required to bite through sample.
   B. *Cohesiveness:* Degree to which sample deforms before shearing.
   C. *Moisture Release:* Amount of juiciness.
   D. *Uniformity:* Degree to which force needed to shear sample is the same across bite area.

IV. Chew Down for fragmentation: Take warm sample, 1" cut align as per partial compression for first chew, keeping sample on same plane, turn 90° and realign as before for second chew and evaluate for:
   A. *Fragmentation:* (2 chews) Check the appropriate box, giving additional information that seems important. Breakdown may be classified as shear completely or incompletely, compacts along shearline, crumbly separation, layered separation, chunky separation.

V. Mastication: Take 1" square cube, place on molars, chew down and evaluate for:
   A. *Juciness:* (7 chews) Amount of moisture released.
   Procedure: Move bulk of mass to center of mouth and using tongue as feeler and evaluate for:
   B. *Size of Chewed Pieces:* (10 chews) The perceived size of clearly separate pieces or pieces held together only by connective tissue web.
   C. *Gristle:* (10 chews) Amount of rubbery particles present.
   D. *Cohesiveness of Mass:* (10-35 chews) Degree to which particles stick together. (Rate when sample is at its maximum and give the chew count at which it was rated).
   E. *Uniformity of Mass:* (25 chews) Degree to which components of the mass are the same.
   F. *Webbed Connective Tissue:* Amount of thread-like tissue present just before swallowing.
   G. *Chewiness:* Number of chews.

VI. After swallow evaluate for:
   A. *Tooth Pack:* Amount of sample remaining in between teeth.
   B. *Mouth Coating:* Amount of film (not taste) left on mouth surface.

VII. Overall:
   A. *Gristle:* (overall impression) Amount of rubbery particles present.
   B. *Webbed Connective Tissue:* (overall impression) Amount of firm thread-like connective tissue present.

VIII. Description of Breakdown (Pay particular attention to the number of chews at which sample has maximum cohesiveness).

Other review papers dealing with puncture (Bourne, 1976), compression (Olkku and Sherman, 1979), deformation (Bourne, 1967) and rupture in relation to strain (Bourne, 1979) merit investigation for research with certain products where these mechanical properties are important. In some products, such as restructured meat, where a crust is formed, measurement of the yield point (instant when a punch begins to penetrate into a food) may be of importance. In the case of deformation, the ability to measure small distances precisely is very important, especially if the meat product is quite firm. Bourne (1967) used the term "small compression" rather than deformation, which he defined as less than 25% absolute compression or less than 50% rupture compression.

There may be other types of mechanical properties presently being measured in other food and non-food products that merit consideration for use with meat products. Busche (1967) published an extensive glossary of terms and definitions of mechanical properties. Some of his definitions, which may be relevant to meat products, are as follows:

Breaking load. Load which causes fracture in tension, compression, flexure or torsion tests.

Creep. Deformation that occurs over a period of time when a sample is subjected to a constant stress at a constant temperature.

Elasticity. Ability of a sample to return to its original shape when load causing deformation is removed.

Flexural strength. Maximum fiber stress developed in a specimen just before it cracks or breaks in a flexure test.

Modulus of elasticity. Rate of change in strain as a function of stress.

Shear strength. Maximum shear stress that can be sustained by a material before rupture.

Strain. Change per unit length in a linear dimension of a sample.

Stress. Load on sample divided by the area through which it acts.

Stress-strain ratio. Stress divided by strain at any load or deflection.

Yield strength. Indication of maximum stress that can be developed in a material without causing plastic deformation.

Sensory Methods

The intent here is not to go specifically through all the various sensory methods available to researchers interested in this approach to measuring meat texture, but rather to indicate what systems are available and have been used with meat products. From a general viewpoint, there are several publications that should be investigated by individuals developing research programs in this area (ASTM, 1968; Larmond, 1970; Abbott, 1973; Larmond, 1976; Dikeman, 1977; AMSA, 1978; Carlin and Harrison, 1978; Cross et al., 1978a; Berry, 1980; IFT, 1981; Weiss, 1981). Some of the various sensory methods and scoring systems that may be useful in certain studies are identified in Table 1 (Abbott, 1973).

One approach that has been used to determine the specific textural properties of a food by sensory means is that of texture profiling. In this system, the mechanical, geometrical and fat and moisture characteristics are assessed. Furthermore, the degree to which the characteristics are present and the order of appearance can also be determined. Details of training a texture profile panel have been reported by Szczesniak et al. (1963), Civille and Szczesniak (1973), Civille and Liska (1975) and Szczesniak et al. (1975). At the USDA Meat Science Research Laboratory in Beltsville, MD, we have developed a texture profile evaluation system for restructured beef steaks. The characteristics and definitions for that system are given in Table 2. Recent publications have dealt with efforts to relate expert and consumer evaluations of texture (Moskowitz et al., 1979; Szczesniak, 1979 and Cardello et al., 1982a) and rescaling texture profile systems with magnitude estimation (Cardello et al., 1982b).

Many studies (Szczesniak, 1968; Bouton et al., 1975a,b; Voisey et al., 1975; ASIM, 1976; Segars et al., 1977; Hayward et al., 1980; Moskowitz, 1981) have dealt with attempts to relate instrumental with sensory approaches to measuring texture. Quite often the researcher is faced with the need, due to time and financial support, to be very efficient in obtaining texture data. Often, instrumental approaches meet this need more fully than sensory approaches. However, many studies with meat products have failed to show the degree of relationship required to substitute one approach for another. The determination of instrumental-sensory texture approaches that yield similar responses is certainly an important area for further research.

Discussion

Question: If a high correlation is obtained between the sensory panel and, for example, the Warner-Bratzler shear, then why not just use the shear?

Answer: One problem with this approach is in knowing whether the shear is actually measuring the same texture components as the panel. Too often, researchers force the panel to agree with the shear when it is what the panel does or determines that should be more closely associated with consumer preference. The mechanical approach is often easier and less costly, but with a test like shear, it may also incorporate compression and tensile as well as shear and when a difference exists between samples, it can't be determined what textural property caused the difference. The thing we have to remember is that we are dealing with the human's perception of texture in foods.

Question: How sharp or dull should a Warner-Bratzler shear machine blade be for use in measuring meat texture?

Answer: This may depend to some degree on the product being tested. Probably more importantly, one should insure each time that the sharpness or dullness of the blade is the same. For a complete evaluation of the many factors that can affect Warner-Bratzler shear values, one should review the paper by Voisey, P. W. and E. Larmond. 1974. Examination of Factors Affecting the Performance of Warner-Bratzler Meat Shear Test. Can. Inst. Food Sci. Technol. J. 7:243.

Question: What is available in the way of meat texture measuring devices for companies to use in all their plants that are inexpensive, yet will give meaningful daily information to quality control and insure uniform meat texture?

Answer: There appears to be a considerable need for this type of equipment, but, as of now, the equipment doesn't exist that meets the criteria of being inexpensive, precise, rapid and capable of easily handling a wide variety of meat products.

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