Tenderness Evaluation in Poultry Meat

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Introduction

Within recent years the poultry industry has experienced a dramatic increase in consumer consumption of boneless breast meat. Total per capita consumption of poultry meat has doubled in the past 30 years alone, increasing from approximately 48 lbs in 1970 to approximately 100 lbs in 2003 (ERS, USDA). Furthermore, not only has consumption increased, but the markets have changed also. Today, approximately 90% of the market consists of parts and further processed products compared to 20% in 1960. The demand for boneless breast meat has steadily increased over the past 20 years. This increasing trend is in part due to the poultry industry's aim to provide lean, convenient products and to focus on the further processed market. In efforts to meet increased consumer demand for boneless breast meat, there has been increased pressure on plants to efficiently produce broiler breast meat, often resulting in shortened aging times in efforts to reduce production costs. However, because changes in aging periods can affect meat tenderness, processors have had to evaluate various means of increasing production of boneless meat without negatively affecting overall consumer acceptance.

Currently, it is recommended that broiler carcasses be stored under refrigeration for 4-6 h before deboning in order to avoid the toughening that accompanies pre-rigor harvesting of broiler breast meat (Stewart *et al.*, 1984; Dawson *et al.*, 1987; Lyon *et al.*, 1989). Since the length of time required for holding carcasses slows production and is therefore expensive, alternative methods such as early harvesting or hot boning of broiler breast fillets have been explored to decrease costs. However, harvesting broiler breast fillets immediately after feather picking or carcass chilling increases meat toughness due to muscle stimulation prior to the completion of rigor mortis development (Stewart *et al.*, 1984; Sams and Janky 1986; Thompson *et al.*, 1987). This processing technique (early deboning) has been shown to decrease costs to the processor, but invariably yields meat with a wide range in tenderness that can cause unacceptable toughness in the final product (Sams, 1994). Innovative techniques such as pulsed electrical stimulation, (Lyon *et al.*, 1989; Sams *et al.*, 1989) wing restraints or tensioning (Papa *et al.*, 1989; Lyon *et al.*, 1992a), post-chill flattening or extended holding of deboned breasts (Lyon *et al.*, 1992b), marination (Alvarado and Sams, 2004), and various combinations of these techniques (Birkhold *et al.*, 1992; Lyon and Dickens, 1993; Dickens and Lyon, 1995) have been devised to eliminate the need for postmortem aging. However, these techniques have not been widely utilized to date, and often have variable results in commercial settings.

Tenderness has been noted as the most important factor in consumer perception of palatability or quality of meat products (Savell *et al.*, 1989); therefore, this attribute has drawn the most attention from researchers (Li *et al.*, 2001). As a result, many methods exist for measuring tenderness of broiler breast meat. Instrumental analyses, descriptive analyses, consumer sensory evaluations, or combinations of the tests have been utilized for assessing meat tenderness.

Instrumental methods such as the Allo-Kramer shear compression system (multiple blade), Warner-Bratzler Shear Blade, and Texture Profile Analysis (TPA) are commonly used within the poultry industry for evaluating tenderness in broiler breast meat (Sams *et al.*, 1990). Descriptive analyses in conjunction with consumer sensory analysis are also methods that researchers use for assessing attributes related to tenderness of poultry meat. These types of tests are very reliable and have been shown to be correlated with instrumental analyses (White *et al.*, 1964; Palmer *et al.*, 1965), however, can be extensive and exceedingly time consuming.

Other types of instrumental tests that have been utilized within the food industry for evaluating texture and tenderness that includes the Craft knife energy test and needle puncture test. However, these tests have not been successfully utilized within the meat and poultry industries. More recently, a new shearing technique using a razor blade has been evaluated for monitoring poultry meat tenderness. This new technique has similar predictability of tenderness as other common methods, but requires less sample preparation making it a better alternative for its ease of use (Cavitt *et al.*, 2001, 2004).

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Factors Influencing Poultry Meat Tenderness

Tenderness is a major quality determinant and probably the most important sensory characteristic of meat (Deatherage, 1963). Many external factors contribute to the wide variation in meat tenderness. These factors can be related to the bird and environment, processing conditions, and cooking methods. Age, strain, and sex as well as environmental and nutritional stresses have all been shown to influence the variation in tenderness among meat samples (Guhne, 1970; Lyon and Wilson, 1986; Smith and Fletcher, 1988; Sams, 2002). However, processing conditions also play a significant role in the development of tough or tender meat. Because of the overall uniformity of commercial broilers today, it is most likely that processing conditions such as early deboning play a bigger role in meat tenderness variation than other factors. Additionally, cooking methods, which can affect moisture retention, can influence perceived meat tenderness.

There are intrinsic factors that are responsible for meat texture which include the myofibrillar component, connective tissue, and juiciness of cooked products. The contractile state of the muscle (myofibrillar component) is probably the most important influence in meat tenderness in market aged (6-8 weeks) broilers. The contractile state of the muscle can be determined by measuring individual sarcomeres, with shorter sarcomeres being strongly correlated with tough meat (Locker, 1960; Herring *et al.*, 1967) (Figure 1). The contractile state of the muscle is influenced by the conversion of muscle to meat (rigor mortis development). During this conversion, which begins at the time of slaughter, muscle pH declines due to an accumulation of lactic acid in the muscle resulting from the loss of the circulatory system. In addition, ATP content declines as the muscle shifts from aerobic to anaerobic metabolism and as the muscle continues to use energy. This rigor period takes approximately 4 h in broilers (Kijowski *et al.*, 1982). Although there is a natural shortening of muscle sarcomeres due to the increased actomyosin bond formation during rigor, there are times at which the sarcomeres can shorten to a great extent by external stimuli. For example, if the muscle is stimulated by deboning, prior to rigor completion when ATP is present in sufficient amounts, the muscle can shorten thus altering the state of contraction resulting in changes in meat tenderness and acceptance by the consumer (Figure 2). Furthermore, muscles such as the *Pectoralis major* (breast fillet) that are deboned in the pre-rigor state can suffer a greater extent of contraction because once the fillet has been removed from the carcass, the skeletal restraints are no longer present to limit contraction.

The connective tissue component of meat tenderness does not play a major role in meat tenderness of young broilers; however, it can affect older animals such as spent fowl to a greater extent. Collagen is an abundant protein in the body and the predominant form of protein that makes up the epimysium, perimysium and endomysium in muscle tissue. Because of the multiple crosslinks in its structure and the ordered array of the collagen fibrils, collagen is fibrous and has high tensile strength. As animals age, heat stable crosslinks form between collagen fibrils thus further increasing tensile strength (Bailey and Light, 1989) which remains during cooking resulting in tough meat.

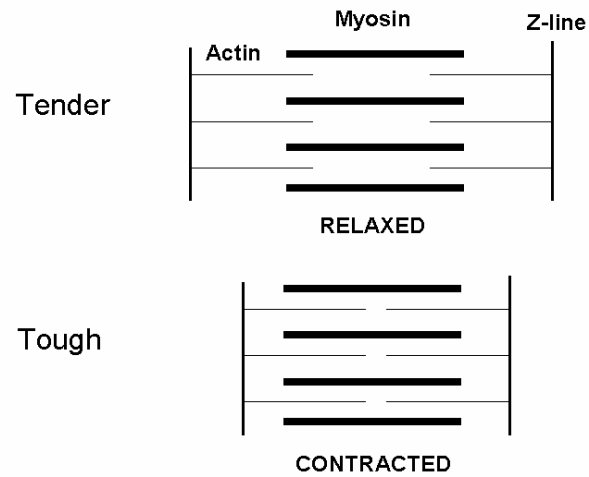

Figure 1. Diagram of the muscle sarcomere in relaxed and contracted states. Shorter sarcomeres are related to tougher meat.

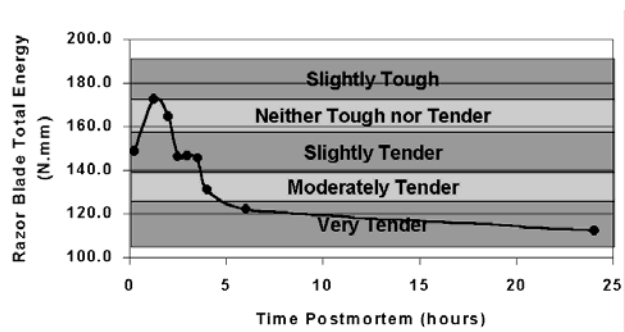

Figure 2. Razor blade total energy (N*mm) of broiler breast fillets deboned at various times postmortem. The shaded portions on the graph correspond to perceived tenderness intensity by consumers.

Juiciness is important in meat tenderness as well because it provides lubrication to the consumer, thus enhancing mouthfeel. Lyon and Wilson (1986) evaluated various rigor conditions and cooking method effects on samples of intact broiler breast fillets and reported that cooking method had a significant impact on moisture and tenderness of the finished product. It has been noted that meat toughness decreases slowly at low cooking temperatures, however at high cooking temperatures a rapid shrinkage of collagen occurs followed by a hardening and toughening of meat. These concepts were further expanded upon by Lyon and Lyon (1990a) in poultry and Roberts and Lawrie (1974) in beef who reported significant differences in moisture content and tenderness utilizing various heating methodologies. Cooking in high heat, low moisture environments can result in a drier, less juicy product causing a decrease in tenderness or perceived tenderness.

Instrumental Methodology for Measuring Poultry Meat Attributes

Today there are many different types of instruments and methods used to evaluate meat texture and tenderness mechanically. Much of the research prior to 1960 had focused on how to make instrumental procedures cut, compress, or manipulate food samples in some way (DeMan *et al.*, 1979). At the time, texture was not viewed as a multi-parameter characteristic, which turned the focus of research on developing a single measurement that could be used to measure texture. Two of the most commonly used instruments for assessing meat tenderness include the Warner-Bratzler (WB) shear device (Bratzler, 1932) (Figure 3) and the Allo-Kramer (AK) compression-shear device (Kramer *et al.*, 1951) (Figure 4). However, with the realization of texture analysis being a multi-parameter characteristic, imitative instrumental tests were developed such as the General Foods Texturometer and Texture Profile Method which has lead to the development of the Texture Profile Analysis (TPA) method which relates perception of sensory texture characteristics. More recent developments in tenderness evaluation of poultry meat include the razor blade shear method (Figures 5 and 6).

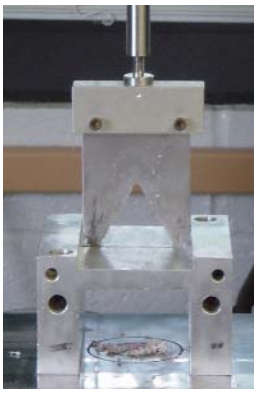

Figure 3. The Warner-Bratzler Shear device with single blade.

Figure 4. The Allo-Kramer Shear device with multiple blades and cell.

Figure 5. The razor blade (8.9 mm width) used in the razor blade shear device.

Figure 6. The razor blade shear method. The intact broiler breast fillet is sheared perpendicularly to the muscle fibers.

Warner-Bratzler Shear

In 1928, the Warner-Bratzler shear blade was first introduced, and since has been widely used within the food and meat industries as a means for evaluating texture and tenderness of meat and other food products. Originally, the WB instrument was comprised of a device where a cylindrical meat core sample was placed through an opening within a rectangular shaft housing a movable shear blade opposed by two shear bars. Samples were cut manually by pulling the blade through the shaft thus severing the cored meat sample. Force required to sever the meat core sample was then indicated by a spring scale as described by DeMan *et al.* (1979).

Since then, the WB has gone through a series of modifications in that WB implements have been fitted for motorized multi-test instruments such as the Texture Analyzer TA-XT2i or other testing machines such as the Instron Universal Testing Machine™. A number of different studies on poultry have been published on how the geometric dimensions of a sample can greatly affect the cutting force of the WB shear which in turn can decrease the accuracy of being able to predict tenderness (Deman *et al.*, 1979; Lyon and Lyon 1990b; Sams *et al.*, 1990). Contrarily to testing performed for beef muscles, testing of poultry muscles has been performed on strips rather than cores. Sample dimensions re-

ported for this test have varied greatly over the decades but it seems that most of the recent research have used a strip width of 19 mm. The strip length and thickness is being measured but not adjusted through trimming and in many instances, two shear values are obtained for each strip. Peak load is recorded and expressed in Kg or Kg/cm2 if the strip height is monitored. As for most instrumental tests performed on poultry and for that matter, many foods, the peak load is the instrumental parameter of choice. This approach neglects the fact that texture in meats even though dominated by the attribute of toughness is a multidimensional quality. There have been only few attempts at evaluating the use of additional parameters, such as the total energy expanded during the test, to describe the multidimensional aspect of meat texture (Davis, 2000).

Allo-Kramer Shear

The AK Shear instrument was first introduced in the early 1950's by Dr. Kramer and was at the time one of the first general purpose test machines used to measure textural properties of foods by linear deformation. Like the WB shear, the AK Shear has gone through a series of transformations from the original design and has been reproduced to be used on other types of machinery such as the Instron Universal Testing Machine™ and Texture Analyzer TA-XT2i.

The AK Shear consists of a moving press, a multiple blade shear device and a stationary shear cell (Figure 4). The set of multiple blades is attached to a system designed to move the blades down and through a sample placed in the cell. As the blades are lowered across and through the sample, initially the sample exhibits compression forces due to the blunt nature of the blades followed by shearing forces which forces the sample out through the bottom of the shear cell resulting in a shear value which is recorded as Kgf/g of sample weight (Kramer *et al.*, 1951).

Studies have been conducted on the effect of sample dimension for measuring poultry meat tenderness. DeMan and Kamel (1981) reported a linear relationship between sample size and meat toughness; with an increase in sample size, an increasing trend in toughness was reported. For testing poultry meat, sample dimensions have varied in the past, but two common dimensions have been used more recently. First, Sams (1990) described a test with on a strip of 0.7 cm height, 2.0 cm width and 4.0 cm long with a crosshead speed of 500 mm/min. Lyon and Lyon (1990) performed a similar test using 1.0 cm wide strips of unspecified length at a crosshead speed of 200 mm/min. In other studies, Lyon and Lyon (1993, 1997) used cubes (either a specific number or a set weight) of 1 or 2 cm sides.

Bouton *et al.* (1975) demonstrated how sample orientation could affect shear results by determining whether or not the shear blade was passed perpendicularly through the sample's muscle fibers. In order to obtain a true shear, meat samples need to be lined up perpendicular to the shear blade. Samples not placed perpendicular to the shear blade could potentially result in slight compression followed by inaccurate shear forces due to the shear blade passing along side (parallel) the muscle fibers.

Texture Profile Analysis

Alternative methods to the WB and AK shear tests have been introduced, including the Texture Profile Analysis (TPA) method (Szczesniak, 1963; Szczesniak *et al.*, 1963) which is an instrumental method that emulates the conditions food is subjected to in the mouth (Bourne, 1978). The need for a multiple-point test was reinforced by Breene (1975) who noted that texture was complex in nature and that multiple-point procedures would be more useful than a single point procedure, which was recently updated by Lyon and Lyon (2000). Early attempts with TPA resulted in instruments that gave similar results to that of the WB and AK tests; only peak force data could be obtained from the resulting deformation curve (Davis, 2000). Texture Profile Analysis is not however solely able to predict tenderness in meat samples. Smith *et al.* (1988) reported that the use of the TPA method on whole muscles might be less acceptable because of the difficulties in application due to the complex and irregular nature of meat samples. Texture Profile Analysis, however, may be used as a tool in conjunction with other methods for correlating specific sensory attributes with various instrumental parameters.

Razor Blade Shear

Research conducted by Cavitt *et al.* (2001) introduced a new instrumental razor blade shear apparatus for predicting tenderness in broiler breast meat, which did not require sample cutting nor was it overly destructive in that only two small incisions were made into the sample. Initial results have indicated that this method is effective in differentiating among meat samples with varying levels of tenderness. Also, the method requires much less sample preparation.

In the razor blade shear method, total energy and maximum force are determined on intact fillets in duplicate on each fillet. In contrast to the WB and AK tests, which have traditionally been measured in Kg, the razor blade method is measured in N for force and N*mm for total energy. This method has been conducted using a Texture Analyzer with a 5 kg load cell using a razor blade with a height of 24 mm and a width of 8.9 mm (Figure 5) set to a penetration depth of 20 mm. Crosshead speed is set at 10 mm/s and the test triggered by a 10 g contact force. Blades should be replaced every 50 samples (2 shears per fillet), or 100 shears, and recalibrated in order to eliminate dulling of blades. The razor blade shear force (RBF, N) is calculated as the maximum force recorded, while the razor blade shear energy (RBE, N*mm) is calculated as the area under the force deformation curve from the beginning to the end of the test (Cavitt *et al.*, 2004). Like the AK and WB, the RB test is conducted so that fibers are sheared perpendicularly, but with more accuracy because the fillet can be adjusted to ensure that fibers are perpendicular upon shearing (Figure 6).

Sensory Methods for Assessing Poultry Tenderness

Descriptive analysis in its purest form can be defined as a sensory evaluation method used when detailed information (qualitative or quantitative) is needed about a given product (Meilgaard *et al.*, 1999). With descriptive analysis, sensory attributes of a product are identified, described, and quantified using human subjects who have been trained for a given product (Lawless and Klein, 1991). Meullenet *et al.* (1998) affirmed that descriptive analysis is the most sophisticated sensory method available and is the only method allowing for discrimination between products based upon intensity differences.

Today, many different descriptive analysis methods exist for assessing tenderness in poultry products including the Texture Profile Method (TPM) and Spectrum Method. Descriptive analysis in meat products has historically been reported principally on formulated meat products, including restructured patties or steak-type products (Lyon *et al.*, 1980; Cohen *et al.*, 1982; Cardello *et al.*, 1983; Berry and Civille, 1986). Palmer *et al.* (1965) along with Simpson and Goodwin (1974) were among the first to report sensory and objective aspects of tenderness analysis in combination with fully cooked broiler breast meat.

A study conducted by Lyon and Lyon (1990a) focused on establishing a relation between sensory and objective texture profiles for whole muscle broiler breast fillets at varying postmortem deboning times in conjunction with dissimilar cooking methods. Results from this study showed that both sensory and objective data were able to identify differences in deboning time and cooking method. However, when comparing between sensory and objective texture profiles for whole muscle broiler breast meat, low correlations were reported. The low correlation between the objective and sensory attributes could possibly be a direct result from individual uniqueness and complexity in the geometric make up of whole muscle products.

Consumer sensory evaluation is a common method utilized by many companies in product development and marketing areas as a means for assessing textural attributes of a given product. This type of evaluation is able to give multiparameter data to researchers that instrumental analyses often times cannot. However, conducting sensory panels can be relatively expensive and time consuming. Recently, there has been vast attention paid to the area of designing instrumental tests that can predict consumer response in order to alleviate the burden of conducting sensory measurements (Szczesniak, 1987; Lyon and Lyon, 1990b; Meullenet *et al.*, 1997; Davis, 2000). The need for correlating instrumental data to sensory analysis exists primarily as a means for quantifying human perception of textural properties in food products.

Correlations Between Sensory and Instrumental Tests

Szczesniak (1987) reported that the quality of correlations between sensory and instrumental measurements is a primary concern that faces researchers in both basic and applied areas of texture studies. Factors including improper execution of sensory tests, inadequate knowledge of what a particular instrumental test actually measures, sampling errors and heterogeneity of food products, and interpretation of the meaning of the correlation coefficient can potentially lead to poor correlations between sensory and instrumental data as described by Szczesniak (1987). These problems were further elaborated upon in relation to meat tenderness by Kapsalis and Szczesniak (1976).

Today, a large majority of research that is geared towards the evaluation of textural and tenderness attributes in meat identifies these attributes as sensory quality parameters that must show a high correlation to instrumental analysis in order to accurately predict tenderness. Closely monitoring and reproducing the exact testing conditions for both instrumental and sensory evaluations are factors that can greatly enhance correlations between the two tests. Other factors including increasing the number of times a sample was passed through a test cell (taking multiple readings from an individual sample) along with adjusting speed at which the force is applied have been shown to increase correlations between instrumental and sensory evaluation (Szczesniak, 1987).

Researchers have reported high correlations between instrumental methods and sensory evaluations. Lyon and Lyon (1990b) reported correlations of $r = 0.82$ and $r = 0.84$ for predicting the intensity of tenderness (consumer sensory) of cooked broiler breast fillets from instrumental tenderness readings (WB and AK). Cavitt (2004) reported that for overall acceptability of texture, WBForce, AKSV, and RBEnergy (R^2=0.94, 0.93, and 0.87, respectively) were better predictors for the development of texture acceptability as compared to RBForce (R^2=0.71). Similarly, overall acceptability of tenderness was better predicted by WBForce, AKSV, and RBEnergy (R^2=0.95, 0.90, and 0.86, respectively) as compared to RBForce (R^2=0.71). Relationships between instrumental and descriptive sensory for the razor blade method were also highly correlated ($0.66<R^2<0.86$) for such sensory attributes as initial hardness and chewdown hardness (Cavitt *et al.*, 2004). When comparing common instrumental methods and their relationship to sensory evaluation, Cavitt (2004) determined that for both descriptive and consumer sensory analysis, RBEnergy, WBForce, and AKSV performed similarly for predicting the tenderness of cooked broiler breast meat. However, using the razor blade method requires less sample preparation and is therefore more efficient.

Conclusion

With the increasing demands of boneless breast meat and further processing, processors are moving towards shortened aging periods, which can lead to increased meat toughness. Additionally, by practicing early deboning, the uniformity of the product in terms of tenderness can be compromised. Therefore, it is imperative for processors to assess tenderness in their final product as quickly, accurately, consistently, and economically as possible in order to ensure consumer acceptance. Strong relationships have been established among instrumental shearing techniques and consumer acceptance of products. Therefore, the use of instrumental shearing methods (RB, AK, WB) would be rapid and accurate for monitoring tenderness of the final product compared to conducting sensory evaluations on a regular basis.

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