

## Tenderness and Textural Analysis Posters

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### Post-Mortem Aging and Injection Treatments to Enhance Beef Tenderness

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Enhancing and understanding the tenderness of beef has been an on-going research topic. Recently, injection of compounds into fresh beef muscle is an active area of research. In this preliminary study, four cows of E maturity were the source of eight strip loins. The steaks from the strip loins were split into treatment groups and injected at 24 hours post-mortem to a 10% level (v/w) with one of the following: 1) water, 2) NaCl/sodium tripolyphosphate, 3) CaCl<sub>2</sub>, and 4) NaCl/sodium tripolyphosphate/CaCl<sub>2</sub>. Warner-Bratzler shear force measurements, myofibril fragmentation index (MFI) values and SDS-PAGE data were collected at 3 and 7 days post-mortem. The results indicated that injection with NaCl/sodium tripolyphosphate, CaCl<sub>2</sub> or NaCl/sodium tripolyphosphate/CaCl<sub>2</sub> resulted in lower Warner-Bratzler shear force values than obtained in the water-injected control. Injection with the two NaCl/tripolyphosphate-containing solutions appeared to have only limited effects on post-mortem proteolysis as examined by MFI values and SDS-PAGE analysis techniques. Injection with CaCl<sub>2</sub> alone caused increased proteolysis as shown by MFI and SDS-PAGE. These preliminary results suggest that different post-mortem tenderization mechanisms may occur by using these post-mortem injection treatments.

### Ante- and Post-Mortem Factors Influencing Beef Tenderness

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Effects of gender, frame size, chronological age, post-mortem storage length, quality grade (QG), broiler temperature and degree of doneness on beef steak tenderness were

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investigated. Rib steaks from 14 mo. old crossbred bulls, steers and heifers broiled to 64°C had similar sensory tenderness scores and Warner-Bratzler shear force values (WBS). Steaks from small-framed cattle, regardless of gender, were more tender than those from large-framed. Strip loin, top round, and clod (*Infraspinatus M.*) steaks were compared from heifers slaughtered at 11, 13 or 15 mo. of age. Strip loin steaks from 11 mo. old cattle scored higher for tenderness than those from 15 mo. old. Steaks from strip loins fabricated from carcasses at 18°C were compared with those fabricated at 2°C; were less tender at 30 d post-mortem (PM) and similar at 60 d PM. A 21% reduction in WBS from day 30 to day 60 PM was observed. USDA Select strip loins, tenderloins and top sirloin butts stored fresh 36-53 days PM were compared with similar cuts from USDA Choice frozen at 4 days PM. Fresh USDA Select tenderloin and top sirloin steaks were scored more tender and had lower WBS than those from frozen Choice. Strip loin steaks from USDA Standard were less tender than those from Prime. Panelists scored steaks between the Select and Choice QG similar for tenderness. Broiler temperature (246° or 316°C) had no effect on tenderness. Regardless of QG, steaks broiled to 63°C were rated more tender and had lower WBS than those heated to 70°C. Variation in beef steak tenderness within USDA Select and Choice may be minimized when steaks are broiled to a medium-rare degree of doneness.

### Effect of Biological Type of Cattle on Meat Tenderness

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Twenty-two sire breeds representing diverse biological types of cattle have been evaluated during the first four cycles of the bovine germplasm evaluation project at MARC. Sire breeds and their biological classifications include: Jersey and Longhorn (1), Angus, Hereford, Red Poll, Galloway and Shorthorn (2), South Devon, Pinzgauer, Tarentaise (3), Brahman, Sahiwal and Nellore (4), Simmental, Brown Swiss, Gelbvieh, Maine Anjou, Salers (5), Piedmontese, Limousin, Chianina and Charolais (6). Classification was based on growth rate and mature size, lean-to-fat ratio, age at puberty and milk production. Sires were mated by artificial insemination to Hereford and Angus cows. The number of steer progeny per sire breed ranged from 54 to 452. The steers were fed a corn-corn silage diet from weaning to slaughter (169 to 329 d on

feed). Tenderness determinations were made on ribeye steak *longissimus* muscle after 4 to 7 d post-mortem aging. A log transformation was conducted before statistical analysis to remove year-to-year variation in experimental conditions and protocol. Warner-Bratzler shear force and sensory panel tenderness ratings indicate that steers sired by Piedmontese, South Devon, Jersey and Pinzgauer tended to produce more tender meat. *Bos indicus* crosses (biological type 4) produced meat that was less tender and particularly more variable in tenderness. Meat from a majority of the sire breeds was very similar in mean tenderness. This was partially due to the large amount of variation in tenderness within sire breeds. To maximize improvement in meat tenderness, selection must be among and within breeds.

## Changes in Meat Tenderness From Slaughter to 14 Days Post-Mortem

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A novel approach was used to measure the tenderness of prerigor ovine *longissimus* muscle by avoiding the confounding effects of heat-induced shortening resulting from cooking prerigor meat. The objective was to determine the inherent tenderness of the muscle at the time of slaughter and to monitor changes in tenderness during rigor development and post-mortem aging. Nine Romanov and twelve Finnsheep rams were slaughtered at 49.3 kg live weight. Samples of *longissimus* muscle were removed at 0, 3, 6, 9, 12, 24, 72, or 336 h post-exsanguination. Five of the eight sample times could be represented in each carcass. All carcasses were sampled at 0, 12, and 24 h. Each carcass was sampled at either 72 or 336 h and at either 3, 6 or 9 h. Muscle samples were clamped between two metal plates before excision to prevent shortening. The samples were frozen at -30°C, then stored at -5°C for 10 d to allow glycolysis to proceed to completion and, thus, full rigor mortis was obtained. *Longissimus* muscle was then cut into chops, cooked and shear force determined. Sarcomere length decreased through 24 h post-mortem, then increased slightly through 336 h post-mortem. Warner-Bratzler shear force values were the same at 0 and 3 h, increased from 3 to 24 h and then declined through 336 h post-mortem. These data imply that ovine muscle at slaughter is intermediate in tenderness, rigor shortening toughens the meat and proteolysis tenderizes the meat, resulting in more tender meat after 14 d aging than at slaughter.

## Calcium Chloride Injection/Infusion to Ensure Heat Tenderness

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Experimentation involving the role of the calpain proteolytic system in post-mortem tenderization led to the discovery that

elevating the calcium concentration of muscle by infusing calcium chloride immediately post-mortem would result in maximizing tenderization by 24 h post-mortem. The initial work involved infusing lamb carcasses immediately post-mortem with 300 mM CaCl<sub>2</sub> at 10% of live weight. This level of CaCl<sub>2</sub> was by design much more than necessary, but was used to find out if tenderization would be affected. The process was used successfully on various meat sources expected to be tough. It was recognized that this process had potential for ensuring tenderness in the beef industry. Subsequent studies were designed to modify the process for industry application. Questions that had to be answered included: 1) Could injection be used instead of infusion to speed up the process and avoid inspection problems? 2) Could CaCl<sub>2</sub> be added post-rigor rather than prerigor to avoid grading problems and hot-boning? 3) What effect did the process have on flavor, lean color and shelf-life? and 4) What would consumers think of the product? This poster chronicles the research that demonstrated the universal application of the calcium-activated tenderization (CAT) process, modified the protocol for commercial use and tested the process under commercial conditions.

## Dynamics of Alpha-Actinin in Relation to Z-line Weakening

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Alpha-actinin is an actin-binding protein located in the Z-line of myofibrils, and is believed to play a major role in stabilizing the Z-line. A structural change that occurs upon aging is Z-line weakening, which may be responsible for the increase in tenderness. We have investigated "in vitro" Z-line weakening of bovine myofibrils using limited chymotryptic digestion. As shown by others, mild proteolysis results in loss of Z-line density when myofibrils are observed by phase-contrast microscopy. Immunoblot analysis of the digest supernatants with polyclonal anti- $\alpha$ -actinin showed that  $\alpha$ -actinin was present as a polypeptide of the same or slightly lower MW than the parent molecule. Immunofluorescence microscopy of the myofibrils with anti- $\alpha$ -actinin showed a decrease in Z-line fluorescence upon limited digestion. When control myofibrils were incubated with fluorescently labeled  $\alpha$ -actinin, the fluorescence was observed solely in the Z-line, and was enhanced upon limited proteolysis. Studies with control myofibrils showed that fluorescent  $\alpha$ -actinin binding at the Z-line was not blocked by pre-treatment with unlabeled  $\alpha$ -actinin. Also, time-course studies suggested that fluorescent  $\alpha$ -actinin was slowly incorporated into the Z-line. These studies demonstrate that: 1) loss of Z-line density is associated with  $\alpha$ -actinin release from the myofibril; 2) the binding sites for  $\alpha$ -actinin are not lost upon Z-line weakening; 3)  $\alpha$ -actinin in the Z-line is in a dynamic equilibrium with a soluble pool. Future work should focus on characterizing the other peptides that are released upon limited digestion and the protein interactions which stabilize Z-line structure.

## The Effects of Ante- and Post-Mortem Treatments on Bull Beef Palatability and Consumer Acceptance

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A total of 120 bulls each weighing approximately 500 kg were used to evaluate the effects of withholding feed and water for various intervals pre-slaughter, ante-mortem supplementation with an electrolyte solution, and post-mortem electrical stimulation on the cooking and palatability attributes and consumer acceptance of boneless rib steaks aged for 6 days at 1°C. The results clearly showed the detrimental effects of withholding feed and water pre-slaughter and the beneficial effects of post-mortem electrical stimulation on the eating quality of bull beef aged for 6 days at 1°C. Taste panel ratings of palatability attributes between electrolyte-treated and untreated animals did not differ significantly. However, consumer evaluations indicated a lower overall palatability rating for electrolyte-treated bulls. The results clearly indicate that feed and water deprivation is detrimental to the palatability attributes and consumer acceptance of aged bull beef.

## Determination of Threshold for Beef Tenderness by Consumers

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Steaks from the rib, loin and round varying in marbling, maturity and Warner Bratzler shear force values were eaten by 70 consumers to determine the consumer threshold for beef tenderness in both the home and the restaurant. The consumer panelists represented a wide range of ethnic origins, income groups and education levels. The consumer panelists were pre-selected to cook beef steaks to a medium degree of doneness (70°C) with dry heat cookery. Steaks were fabricated into 2.0 cm thick portions and consumed by each panelist in their home and in a "white table cloth" restaurant. Each consumer rated each steak for tenderness and overall acceptability on an 8-point scale. A trained 8-member sensory panel also rated the steaks for tenderness; Warner Bratzler Shear (WBS) force values were taken on three 1.3 cm thick cores. Consumers determined the threshold for beef tenderness under restaurant conditions occurs at approximately 5.0 kg of WBS. The rating scale threshold occurred between a 4 (slightly tough) and a 5 (slightly tender) score. Beef steaks consumed in a restaurant had to be at least "slightly tender" to produce 99% customer satisfaction. The threshold for beef tenderness in the home was approximately 3.0 kg of Warner Bratzler Shear. These results indicate that the same consumers are more discriminating in the home than in restaurants. The rating scale threshold for steaks consumed at home occurred between a 3 (moderately tough) and a 4 (slightly tough). The atmosphere in a restaurant setting appears to significantly influence the consumer perception of beef steak tenderness. Consumers appear to be less discrimi-

nating under restaurant conditions than in their home. The results from this investigation clearly indicate different thresholds for beef tenderness at home and in a restaurant; therefore, the threshold may be influenced by the environment under which beef is consumed.

## Relationship of Various Objective Tests to the Sensory Perception of Tenderness in Broiler Breast Meat

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The most significant variable in the texture of deboned broiler breast meat is post-mortem (PM) aging time prior to removal of the muscles from the skeletal restraints. Tenderness of the meat was a non-issue as long as ice-packed whole carcasses were marketed. Consumer complaints of toughness began when the marketing changed to deboned and further-processed products.

Traditionally, objective shear values (Warner-Bratzler and Allo-Kramer) have been used to determine the tenderness of cooked meat; however, there has been a lack of corresponding sensory data to validate the significance in the range of shear values. Using PM deboning times ranging from less than 15 minutes to 24 hours, this relationship between the objective values and the panels' perception of tenderness was established. Shearing tests and the Texture Profile Analysis procedure were used. Trained and untrained panelists evaluated the samples.

Differences in tenderness due to PM deboning times were noted by panelists and objective tests. For the Warner-Bratzler, values greater than 12.6 kg were considered "very tough," while values less than 3.62 kg were "very tender." Allo-Kramer (multi-blade) values greater than 14.25 kg/g were "very tough," while values less than 5.99 kg/g were "very tender."

## Ultrasonic Elastography to Evaluate Meat Structure and Quality

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**Beef Quality.** Three muscles (*Longissimus dorsi*, *Gluteus medius* and *Semitendinosus*) from three A-maturity beef carcasses containing Moderate, Small, and Slight marbling were excised 24 hr. post-mortem. Elastography was conducted on an 8 x 8 x 5 cm block from each muscle. Sensory analysis, Warner-Bratzler shear force, and chemical analyses (myofibrillar fragmentation, total and soluble collagen, fat content, and sarcomere length) were conducted on adjacent steaks. Haralick image parameters from the beef elastograms were highly correlated to sensory muscle fiber tenderness, connective tissue amount, overall tenderness and flavor intensity ( $P < .05$ ). Sarcomere length was highly related ( $r = .70$ ;  $P < .05$ ).

to Haralick parameter 2 (45° angle). These results indicate that structure parameters in elastograms are related to sensory attributes and sarcomere length in three beef muscles from beef carcasses varying in marbling score.

**Turkey Quality.** Turkey breast muscle from unstressed birds (first birds slaughtered from a house) and stressed birds (last birds slaughtered from a house) were evaluated for objective and subjective color, pH, temperature and water-hold-

ing capacity (WHC). Elastography was conducted on an 8 x 8 x 5 cm muscle segment. Muscle from stressed birds was lighter, had lower pH and lower WHC. Hunter L and b values and final pH were highly correlated ( $P < .05$ ) to Haralick parameter 13 (90° angle). This research, though preliminary data on a small number of samples, indicates that structure within elastograms is related to quality characteristics of turkey muscles.