1997

Predicting Tenderness in Beef Carcasses by Combining Ultrasound and Mechanical Techniques

Gene H. Rouse
Iowa State University

Doyle Wilson
Iowa State University

Mehmet Bilgen
Iowa State University

Viren Amin
Iowa State University

Ronald Roberts
Iowa State University

Extension Number: ASL R1333

Predicting Tenderness in Beef Carcasses by Combining Ultrasound and Mechanical Techniques

Abstract
• Meat tenderness is a concern today in the beef cattle industry, and it will become an even greater concern in the future. • Tenderness is a complex issue, and it is difficult to predict tenderness after cooking by examining raw beef or carcass beef. Unfortunately, tenderness must be evaluated at the carcass level to be a useful tool in the industry. • A star-shaped probe was attached to an InstronÒ machine. This attachment makes it possible to measure tenderness in both raw and cooked Longissimus dorsi steaks. The correlation between raw and cooked was 0.41. • The correlation between cooked star probe values and Warner Bratzler shear values (the standard tenderness measure) was 0.53. • The star-shaped probe applies pressure to beef tissue. This approach was then combined with ultrasound to evaluate firmness or softness of beef tissue. Ultrasound images were collected as increased pressure was applied (elastography). • A probe has been built that attaches to hot carcasses to evaluate this elastography procedure.

Keywords
ASL R1333

Disciplines
Animal Sciences

Predicting Tenderness in Beef Carcasses by Combining Ultrasound and Mechanical Techniques

A.S. Leaflet R1333

Gene H. Rouse, professor of animal science,
Doyle Wilson, professor of animal science,
Mehmet Bilgen, postdoctoral research associate,
Viren Amin, postdoctoral research associate, and
Ronald Roberts, physicist, Center for Nondestructive Evaluation

Summary

- **Meat tenderness is a concern today in the beef cattle industry, and it will become an even greater concern in the future.**
- **Tenderness is a complex issue, and it is difficult to predict tenderness after cooking by examining raw beef or carcass beef. Unfortunately, tenderness must be evaluated at the carcass level to be a useful tool in the industry.**
- **A star-shaped probe was attached to an Instron® machine. This attachment makes it possible to measure tenderness in both raw and cooked *Longissimus dorsi* steaks. The correlation between raw and cooked was 0.41.**
- **The correlation between cooked star probe values and Warner Bratzler shear values (the standard tenderness measure) was 0.53.**
- **The star-shaped probe applies pressure to beef tissue. This approach was then combined with ultrasound to evaluate firmness or softness of beef tissue. Ultrasound images were collected as increased pressure was applied (elastography).**
- **A probe has been built that attaches to hot carcasses to evaluate this elastography procedure.**

Introduction

In recent years, consumer surveys have returned to the industry indicating that one out of every four steaks is less than desirable in tenderness/palatability.

Additional factors make tenderness of even greater concern for the future:

- retail outlets are fabricating less expensive cuts as steaks rather than roasts.
- consumers are cooking beef to a higher degree of doneness – USDA Select cuts are affected more than USDA Choice cuts.
- cattle will be slaughtered with less subcutaneous fat cover – assuming similar genetics marbling level will decrease.

There is a cry throughout our industry to make beef more tender and more consistent. Instruments are currently being developed at several institutions to evaluate tenderness. Instrumentation utilizing B mode real-time ultrasound is being used accurately to predict intramuscular fat level in the *Longissimus dorsi* (LD) muscle on hot carcasses. An ultrasound technique of applying pressure on the LD muscle of a hot carcass while taking a series of ultrasonic images measures tissue elasticity. These measures determined on hot carcasses can be used to sort carcasses into tenderness groups; one must keep in mind, however, that the similarity between raw and cooked beef is relatively low and that tenderness is a complex issue. Tenderness or toughness of beef can be divided into three basic components as shown in the table below. The percentage beside the components reflects the relative importance of reach component assuming the beef was produced from grain-fed calves as determined by a survey of research scientists working on tenderness.

	Percent
Connective tissue	15
Marbling (% intramuscular fat)	35
Myofibrillar protein (post-mortem protein breakdown)	50

The objective of this project is to evaluate mechanical methods to predict the tenderness of cooked beef by measuring raw beef shortly after slaughter. Additionally, can a mechanical method be combined with ultrasound to evaluate the response of pressure on beef muscle to measure firmness or softness of muscle tissue?

Materials and Methods

The cattle used to provide the steaks for the two experiments discussed in this project were calves from the animal breeding project at Rhodes and McNay research farms. Calves were weaned, fed a high-grain ration (80% concentrate) and slaughtered at 14–16 months of age when they would grade 70 percent Choice with 0.4 inches of subcutaneous fat.

Carcasses were allowed a 72-hour chill at the packing plant. A team from ISU was present at the packing plant to collect carcass data. Hot carcass weight, marbling score, fat depth, KPH, and ribeye area were collected to calculate the yield and quality grade of each animal. Firmness, heat ring, color, and texture also were collected to compare visual appearance. The 13th rib section was collected from the left side of each carcass and returned to the ISU Meat Lab. The section was deboned and the LD muscle was sliced to a one-inch thickness. The muscle was then vacuum packaged and aged 12 days at 2 °C, then frozen and stored in a -20 °C freezer.

The LD sample from each carcass was thawed overnight and cooked on an open-hearth broiler set at 302 °C to an internal temperature of 63 °C. A thermocouple was used to track internal temperature. Samples were allowed to cool five hours to reach room temperature. An Instron® machine, Model 4502, with Warner-Bratzler shear (WBS) attachments and crosshead speed set at 250 millimeters per minute, was used to determine shear force values. Seven .5 inch cores were taken from specific locations (Figure 1) on the LD muscle; kg force at maximum load was recorded for each core.

The procedure discussed above details the protocol used at the ISU Meat Laboratory to measure shear force values.

The star probe procedure utilizes an attachment that fits on the Instron® machine. The tip of the probe is star-shaped and resembles a molar. This probe is lowered to the surface of a steak, then the machine is programmed so that the probe is pushed into the tissue until the tissue is compressed to 20% of its original thickness. The force required for this compression then represents peakload for the star-shaped probe. The unique feature of this procedure is that both raw and cooked values can be determined on the same steak -- a feature that is not possible with the WBS.

Results and Discussion

The initial experiment was an attempt to fit the Instron® equipment with a star-shaped probe resembling the surface of a molar. With this mechanical devise, steaks could be compared both raw and cooked. The mean, standard deviation, and range for the seven probes taken on each of the 216 raw or 191 cooked steaks is shown in Table 1. Peakload means in pounds are more than twice as high for cooked steaks as they are for probed raw steaks (11.2 and 5.30, respectively). This result indicates that more than twice the force is required to compress the cooked steak with the star-shaped probe to 20% of its original one-inch thickness than was required for the raw steak.

Table 2 relates the correlations between raw and cooked mechanical tenderness measures. The correlation was 0.41 for peakload force and 0.49 for total energy expended during the compression. These values do indicate that there is a positive relationship between raw and cooked values, and plots of these relationships indicate that carcasses may be sorted into tenderness groups.

A prediction model was developed combining peakload of the raw sample with percent intramuscular fat determined on the hot carcass with real-time ultrasound to predict cooked peakload value. The model predicted 32% of the variation of cooked peakload values with a standard error of prediction of 1.87 pounds. The correlation between actual cooked peakload and predicted cooked peakload was 0.50.

A second study utilizing 97 ribeye steaks compared both raw and cooked star-probe values with cooked Warner-Bratzler shear (WBS) peakload means, standard deviations, and ranges (Table 3). Peakload values for WBS required slightly more than half the pounds of force to shear a half-inch cooked core as compared to the force to compress the star probe to 20% of the steak's original one-inch thickness.

Table 4 shows that the correlations between raw and cooked star-probe peakload values were similar to the result in the initial study -- 0.41. The correlation between cooked star-probe values and WBS values was 0.53.

These results utilizing a mechanical compression probe led to the combining of this technique with a series of real-time ultrasound images to evaluate changes in muscle tissue during compression.

The principles of the elasticity measurement techniques used in this work are similar to those of ultrasonic elastography. The compression against rib bones and use of B-mode images to estimate elasticity in the beef are the new ideas and techniques introduced in this work. Figure 2 shows the schematics of an experimental set-up for data acquisition of ultrasonic A-mode and B-mode techniques. The set-up consists of a personal computer, a stepper motor with controller, a load cell, a display unit, and an ultrasound probe. The load cell measures the amount of external load applied to the probe and is controlled by the stepper motor and controller assembly. For A-mode scanning, the display unit is an oscilloscope connected to a personal computer and a single transducer probe. For B-mode imaging, the display unit is an ultrasound scanner with a linear array transducer. The images of the scanner are captured by a frame-grabber card and stored in the computer for further processing.

In elasticity measurements of beef muscle, the probe is placed against the ribeye muscle across the 12th and 13th ribs to acquire the pre-compressed data. The probe then compresses the muscle against the rib bones to acquire the post-compressed data. The rib bones in this approach also serve as reference ultrasound reflectors for displacement measurements.

For reference measurements and calibration, several phantoms have been produced to mimic the muscle tissue acoustically. A very elastic and flabby gel substance made from synthetic oil was used in the manufacturing of these phantoms. Different processing techniques which add other chemicals and materials into the gel also have been used to produce phantoms with different ultrasonic and elastic properties.

The elasticity predictions using the A-mode and the B-mode techniques are tested against the benchmark Instron® measurement results. Standard procedures for Instron® measurements are followed. A two-cubic-inch sample from each of the ultrasonically evaluated ribeye muscles is subjected to 10% compression with a circular probe at three different locations. The amount of force and energy applied to the sample are recorded as a function of compression. An average from three locations is calculated for each parameter. The Instron® values for the phantoms are taken in the same way. The peakload and energy at the peakload are two parameters used in this work to correlate with the calculated elasticities of the samples.

The preliminary work conducted in the Center for Nondestructive Evaluation laboratory is described in more detail with results in A.S. Leaflet R1222 (1995).

This preliminary laboratory work resulted in the development of a prototype that can be clamped on hot carcasses and used to make measurements in a packing house (Figure 3). A 12.5 centimeter, 3.5 MHz transducer from an Aloka 500® is placed in a guide on the apparatus. Weight is added to an arm attached to a guide resulting in increasing pressure on the transducer which is in contact with the hot carcass. A series of ultrasound images is collected as pressure is increased in incremental steps. This prototype currently is being evaluated in a packing plant.

Implications

Packing house on-line equipment has been developed to determine percent intramuscular fat on hot carcasses. This technology can be combined with elastography and a computerized model developed to sort hot carcasses. A testing facility to simulate a packing house line is needed to validate and transfer this technology to the packing industry. This product quality evaluation must then be combined with a system to predict retail yield before a system will be accepted by the packing industry.

Acknowledgments

This research was supported in part by research grants from USDA-CSRS, the National Livestock and Meat Board, and the Iowa Beef Industry Council.

Table 1. Measuring tenderness with a mechanical star-shaped probe on both raw and cooked ribeye steaks.

	n	Mean peakload, lb ± S.D.	Range, lb
Cooked	216	11.20 ± 2.05	5.43 – 17.82
Raw	191	5.30 ± 0.88	2.99 – 8.38

Table 2. Correlations between raw and cooked mechanical tenderness measures utilizing the star-shaped probe.

	r
Peakload	0.41
Total energy	0.47

Table 3. Comparing the star probe and the Warner-Bratzler shear (WBS) as mechanical methods to predict tenderness.

	n	Mean peakload, lb ± S.D.	Range, lb
Star probe – raw	97	6.29 ± 1.30	4.18 – 10.67
Star probe – cooked	97	10.85 ± 2.35	7.04 – 17.58
WBS – cooked	94	5.79 ± 1.52	3.10 – 9.86

Table 4. Correlations between raw and cooked mechanical tenderness measures utilizing the star-shaped probe and the star-shaped probe (cooked) vs WBS.

	r
Star probe: raw vs cooked	0.41
Star probe vs WBS (cooked)	0.53

Figure 1. Location of cores taken from the 13th rib section.

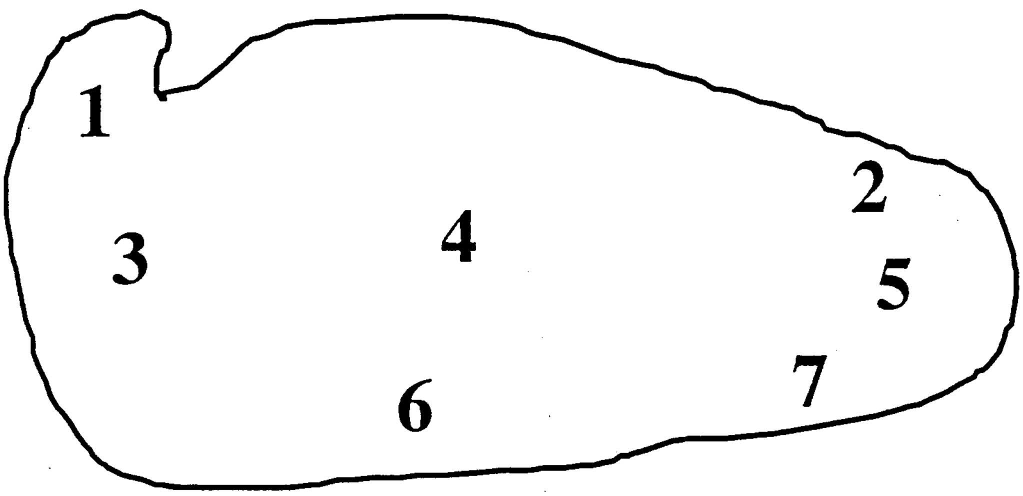

Figure 2. Schematics of ultrasonic elasticity measurement set-up.

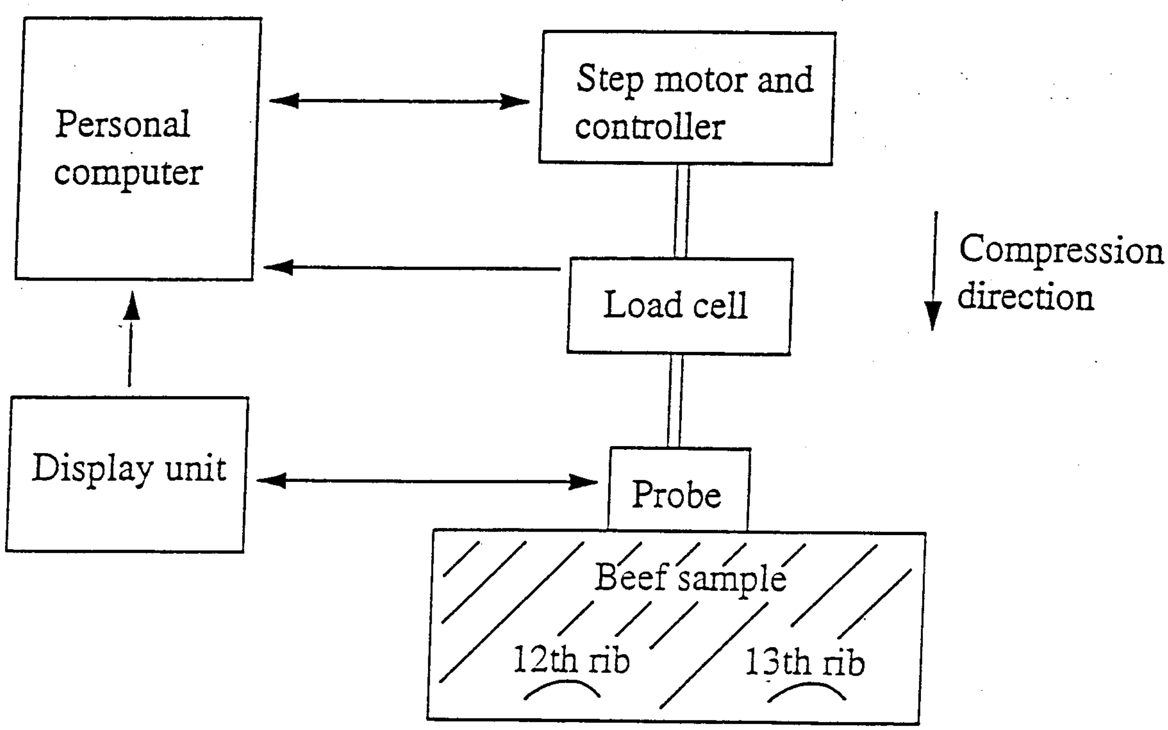

Figure 3. A prototype to collect elastographic measurements on hot carcasses.