

Video Article

Introducing an Angle Adjustable Cutting Box for Analyzing Slice Shear Force in Meat

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Abstract

Research indicates the fibre angle of the *longissimus* muscle can vary, depending upon location within a steak and throughout the muscle. Instead of using the original fixed 45 ° or 90 ° cutting angle for testing shear force, a variable angle cutting box can be adjusted so the angles of the knives correspond to the fibre angle of each sample. Within 2 min after cooking to an internal temperature of 71 °C on an open-hearth grill set at 210 °C, a 1 cm by 5 cm core is cut from the steak, parallel to muscle fibre direction, using 2 knife blades set 1 cm apart. This warm core is then subjected to the Slice Shear Force protocol (SSF) to evaluate meat texture. The use of the variable angle cutting box and the SSF protocol provides an accurate representation of the maximal shear force, as the slice and muscle fibres are consistently parallel. Therefore, the variable angle cutting box, in conjunction with the SSF protocol, can be used as a high-throughput technique to accurately evaluate meat tenderness in different locations of the *longissimus* muscle and, potentially, in other muscles.

Video Link

The video component of this article can be found at <http://www.jove.com/video/50255/>

Introduction

Tenderness is one of the most important quality attributes in meat¹. Inconsistency in beef tenderness has been identified as one of the major problems facing the beef industry². The Warner-Bratzler shear force (WBSF) test, characterized by a triangular hole in a precisely machined shear plate, is the most widespread method used to indicate meat sensory tenderness^{3,4}, as it is the instrumental method that arguably has shown the best correlation with sensory panel scores for meat toughness⁵. However, the slice shear force protocol (SSF) has become an important technique for analyzing muscle texture and tenderness⁶, as an alternative to the standard WBSF protocol⁷. It is beneficial in instances where rapid analysis or a high number of samples need to be processed. For the SSF, only one core is taken from the steak when it is still warm, versus the multiple cores (3-6) taken from the steak usually after 24 hr of refrigeration for the WBSF⁶. From this one slice, the SSF analyzes the average texture of the whole steak⁸, as it has been found that tenderness varies between the lateral to medial sides of the steak⁹, with the center and middle of steaks having the best representation for average WBSF. The downfall to the SSF is that, within a steak, from the lateral to medial sides, there is variation in the shear force values⁹; however, by consistently using the sizing box to make 5 cm sections, it may reduce variability that could come from using different sections of the steak. However, since some steaks are different sizes, a 5 cm slice may occur in different locations on the steak, which could then affect shear force values¹⁰.

On the other hand, the original cutting box designed to obtain the section to be analyzed in the SSF protocol allows only 2 fixed angles, 45 ° and 90 °; however, muscle fibre orientation changes within steaks, and within the muscle¹¹. Shackelford and Wheeler¹² stated that the average *longissimus* angle was 43.8 °, which was close to 45 ° and therefore deemed appropriate when samples were always collected from the same location. However, Derington *et al.*¹¹ reported a range in the angle of the fibres along the *longissimus* muscle between 33.1 ° and 53.9 °. Thus, when, for research purposes, several steaks from the same animal need to be analyzed, assigning all fibre angles to either 45 ° or 90 ° potentially reduces accuracy. The use of a variable angle cutting box may provide a more accurate depiction of maximal shear force, as having the capacity to measure and adjust the cutting angle allows for the slice to consistently run parallel with the muscle fibres.

Protocol

1. Steak Collection

1. Following grading at 24 hr - 48 hr post slaughter, the *longissimus* muscle (either the *thoracic* and/or *lumborum* end) is removed from beef carcasses and collected for quality analysis.
2. The muscle is trimmed of subcutaneous fat and squared off. The muscle is then cut into 2.5 cm (1 in) steaks following safety and food handling protocols. Following the cutting of individual steaks, appropriate labels (animal number, side, muscle location, or time) are placed on the respective steak.
3. Steaks are then prepared for storage. If they are to remain fresh, they are placed on a tray and taken to the grill. If the fresh steaks cannot be cooked immediately, they need to be covered with plastic until cooking can begin, to prevent dehydration. If steaks are to be aged in a cooler, or frozen, the weight is recorded to two decimal places before being placed in an oxygen impermeable vacuum-package bag and sealed using a vacuum packaging machine. Steaks are then placed in their respective long term storage locations.

2. Cooking Procedure

1. If the sample has been frozen, remove from the freezer and place in a 4 °C cooler to thaw overnight.
2. On the day of cooking, pre-heat an open-hearth grill to 210 °C for sample cooking, and prepare the temperature logger system and computer by inserting the thermocouples into the outlets of the scanning device. Lightly grease the grill with vegetable shortening approximately 10 min before cooking begins.
3. Before beginning to cook, remove steaks from the cooler. Remove the sample from its package and blot excess moisture from the steak with paper towel. Record the raw weight of the steak to two decimal places.
4. Insert a thermocouple into the midpoint of the steak along its longitudinal axis. Start the thermocouple scan to record cooking data.
5. Place the steaks on the grill, keeping the thermocouple parallel to the flat cooking surface of the steak and the grill. If the probe is not kept parallel, it can result in improper temperature readings.
6. Cook steaks to an internal temperature of 35.5 °C, then flip the sample over and continue cooking to a final internal temperature of 71 °C. Once the internal temperature is 71 °C, remove the sample from the grill and pull the thermocouple out of the steak.
7. If a cooking weight is desired, allow the steak to cool slightly (1-2 min), then blot the sample with a paper towel to remove excess moisture and weigh sample to two decimal places.
8. If cooking data are required, save the thermocouple scan data.

3. Angle Adjusting and Sample Preparation

1. While the sample is still warm from the grill, make a cut 1 - 2 cm from the lateral end of the steak to create a square end.
2. A 5 cm section across the width of the steak is prepared by using a 'sample sizing box' with a knife notch at 5 cm, parallel to the original cut.
3. The orientation of the muscle fibre angle can be measured by placing a protractor on the knife-cut surface of the steak.
4. The variable angle cutting box is then set to the corresponding angle of the sample by sliding the lower metal plate customized with the bottom holes for guiding the double bladed knife. Tighten the knobs to secure the lower metal plate at the corresponding angle.
5. Place the 5 cm section of the steak into the cutting area of the variable angle cutting box so that the muscle fibre direction is parallel to the angle of the double bladed knife.
6. The double bladed knife is used to cut a 1 cm slice across the previously cut 5 cm piece, so ensure that the knife will pass through the whole sample at the corresponding angle. When placing the steak, ensure that it is touching the edge of the cutting area closest to the user, as the cutting motion will pull the steak towards the user.
7. To cut, insert the double bladed knife into the cutting box and pull the knife to cut the meat into a 1 cm strip. To prevent tearing of the meat, use a slight sawing motion while pulling the knife towards the user. Keep the knife blades against one edge of the guide plate to maintain equal cutting proportions.
8. The result should be a warm, 1 cm thick slice that is 5 cm long, with the fibres consistently running parallel to the slice. This slice is then used for slice shear force analysis of texture in meat.

4. Shear Force Analysis

1. To determine shear force analysis, the slice shear force protocol (SSF) uses the 1 cm by 5 cm slice obtained with the variable angle cutting box. Using a texture analyzer machine with a flat shear slice blade, the analysis is performed on the warm slice.
2. Prepare the Texture Analyzer with a 50 kg load cell and set the shear distance to 48 mm, with a cross head speed of 500 mm/min.
3. The shear is performed once, perpendicular to the muscle fibres to provide an accurate analysis of the maximum force required to shear the fibres in the slice.
4. Once the slice has been sheared completely through the center, save and record the data.

Representative Results

Thirty-one finished commercial beef steers were slaughtered and their carcasses (528 - 601 kg) were split. In order to create variability in tenderness, right sides were immediately stored at 2 °C, while the left sides were held at 10 °C for 3 hr and then at 2 °C. The *longissimus* muscles from right and left sides were removed 24 hr after slaughter. Samples from the right sides ("TOUGH" treatment) were analyzed that day, while samples from the left side ("TENDER" treatment) were aged for 6 d before being analyzed. Two paired steaks were fabricated from the anterior (5th-6th *thoracic vertebrae*), middle (12th-13th *thoracic vertebrae*) and posterior (4th-5th *lumbar vertebrae*) portions of the right and left

longissimus muscles. By sampling two steaks adjacent to one another and performing both the reference WBSF and SSF on the same steak we are able to compare the angle adjustable SSF to the WBSF reference material. Steaks were cooked as described in the preceding procedures. Following a balanced design, each pair of steaks were split into two halves, one medial and one lateral. The medial half of one steak and the lateral half of the second one were used to prepare slices using the angle adjustable cutting box and analyzed with the slice shear force (SSF) protocol. The remaining half steaks were placed in individual plastic bags, submerged in an ice bath to arrest cooking and refrigerated at 4 °C overnight for preparation of 1.9 cm cylindrical cores and analyzed using the reference Warner-Bratzler shear force method (WBSF).

According to the results ($n = 372$), shear force method $\times$ muscle location or steak location interactions were not significant ($P > 0.05$). This means that, regardless of the differences in absolute values from each method, the differences observed among treatments or locations were similar when either method was used to evaluate tenderness in cooked beef. Furthermore, no interactions ($P > 0.05$) were observed with the treatments (tough vs. tender). For the angle adjustable SSF method (**Figure 2**), differences were observed among muscle location ($P < 0.05$). The toughest steaks were those sampled from the middle section of the *longissimus* muscle. Anterior steaks were the most tender samples and posterior samples were intermediate. The same effect was observed in samples analyzed using the reference WBSF method (**Figure 3**). Both Janz *et al.*¹⁰ and Henrickson and Mjose¹³ showed similar results, reporting greatest shear force values in the middle area of the *longissimus* muscle, lowest in the anterior area and intermediate in the posterior area. Janz *et al.*¹⁰ explained these intramuscular differences on factors such as cooling rates, pH decline along the loin, muscle fibre angles and tensions during carcass hanging.

Similar to the study of Shackelford *et al.*⁶ which compared a fixed angle slice shear force to a standard WBSF, the results for the adjustable angle slice shear force were also compared to the standard WBSF in the present study. The coefficient of variation (**Table 1**) is a measure of the variability among samples within each method, and the overall coefficient of variation in this experiment was similar for both methods, regardless of the location along the muscle or within the steak. However, the coefficient of variation for WBSF was consistent between tender and tough samples (23-28%), while for SSF variability ranged from 13.6 for tough samples to 34.2% for tender samples. Thus, more variability was observed for the values from the angle adjustable cutting box in the tender sample, while WBSF shear force resulted in more variability in the tough samples.

After comparing the coefficients of variation, the next step was to determine the correlation (r) between the values obtained by the different methodologies (**Table 2**). Thus, a high correlation ($P < 0.001$) was observed between the values from both methodologies (overall 0.75), being highest (0.84) in the lateral samples from the anterior end and lowest (0.63) in the medial samples from the posterior end. These results are much higher than those reported by Derington *et al.*¹¹, which ranged between 0.38 and 0.62. This may indicate an advantage of the angle adjustable compared to the original 45 ° cutting box, particularly when sampling occurs along the *longissimus* muscle, or from the medial rather than the lateral end of steaks.

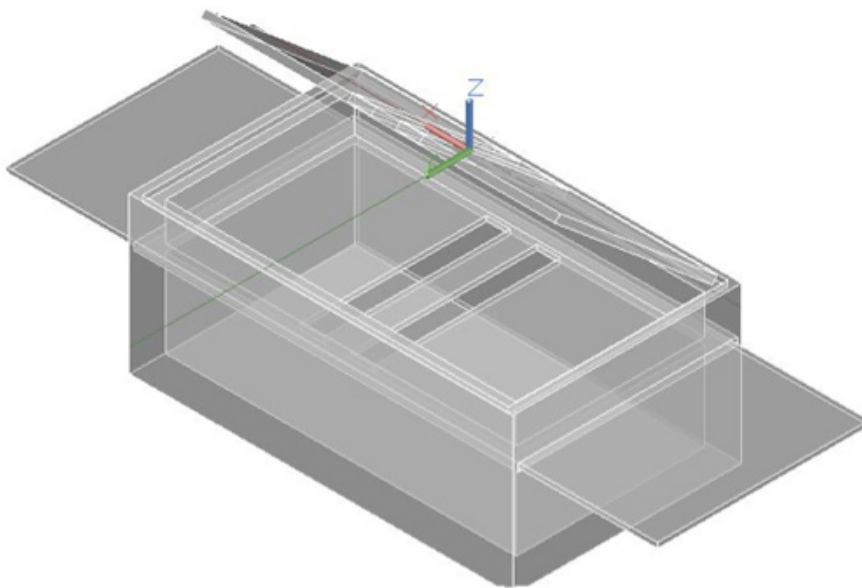


Figure 1. Original design of the angle-adjustable cutting box for slice shear force analysis.

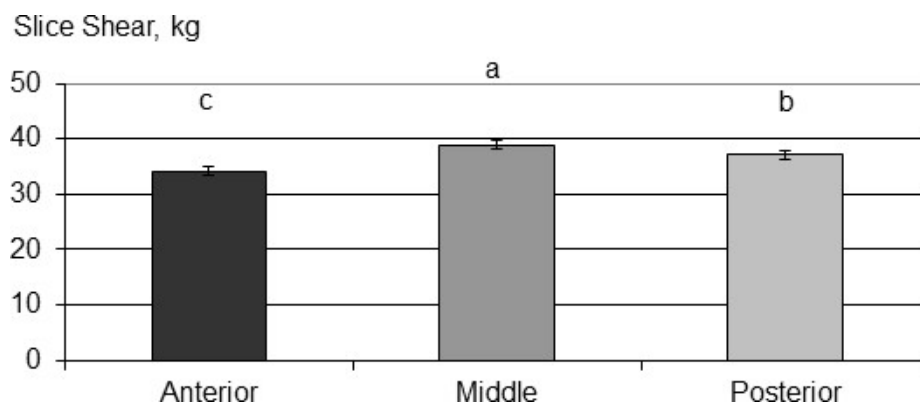


Figure 2. Slice shear force values (angle adjustable box) for steaks from three different locations within the LT muscle (n = 186).

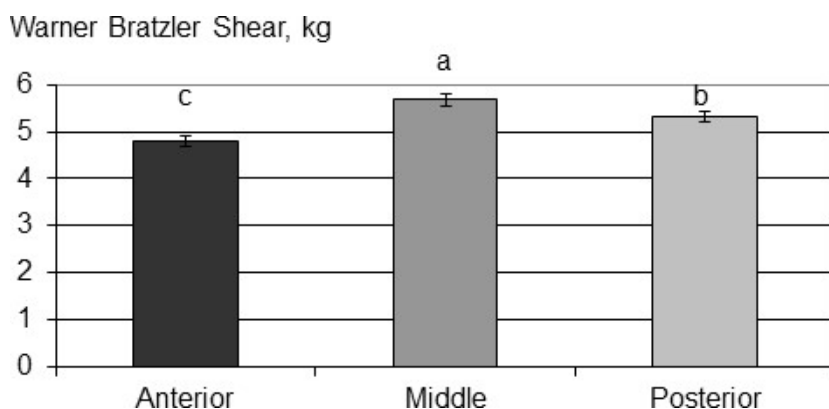


Figure 3. Shear force values (WBSF) for steaks from three different locations within the LT muscle (n = 186). Anterior (5th-6th thoracic vertebrae); Middle (12th-13th thoracic vertebrae); Posterior (4th-5th lumbar vertebrae) ^{a,b,c}Different letters indicate significant differences (P < 0.05).

	Overall	Side		Locations within Loin			Locations within Steak	
		Left (Tender ¹)	Right (Tough ²)	Anterior	Middle	Posterior	Lateral	Medial
Warner Bratzler Shear Force	38.5	28.6	23.1	39.9	36.6	37.7	39.1	37.7
Slice Shear Force	34.9	34.2	13.6	37.1	31.4	34.7	35.7	34.1

Table 1. Coefficients of variation (%) for Warner-Bratzler and angle adjustable cutting box slice shear force values (n = 372). Anterior (5th-6th thoracic vertebrae); Middle (12th-13th thoracic vertebrae); Posterior (4th-5th lumbar vertebrae) ¹Tender: carcasses held at 10 °C for 3 hr post-mortem and then stored at 2 °C and meat aged for 6 days; ²Tough: carcasses stored at 2 °C immediately post-mortem and meat aged for 24 hr.

	Warner-Bratzler Shear Force						
	Anterior		Middle		Posterior		
	Overall	Lateral	Medial	Lateral	Medial	Lateral	Medial
Slice Shear Force	0.751	0.843	0.763	0.693	0.777	0.758	0.634
P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table 2. Coefficients of variation (%) for Warner-Bratzler and angle adjustable cutting box slice shear force values (n = 372). Anterior (5th-6th thoracic vertebrae); Middle (12th-13th thoracic vertebrae); Posterior (4th-5th lumbar vertebrae) ¹Tender: carcasses held at 10 °C for 3 hr post-mortem and then stored at 2 °C and meat aged for 6 days; ²Tough: carcasses stored at 2 °C immediately post-mortem and meat aged for 24 hr.

Discussion

The angle adjustable box ensures the SSF blade always shears muscle fibres at a true perpendicular angle, rather than approximately perpendicular which could happen with a fixed 45 ° angle cut⁸. The application of the variable angle cutting box allows for more accurate depictions of the maximal shear force in a sample, and it is on this basis of improving objective quality analysis techniques that the variable angle cutting box was developed. Furthermore, the wide range of angles presented by the angle adjustable box (30 ° to 60 °) allows for the preparation of samples from muscles other than the *longissimus* for SSF analysis. However, the double bladed knife, set 1 cm apart, may have some flex in the blade which may alter the thickness of the slice, and therefore the shear force. To ensure the variation is reduced, the knives should be as short as possible (5 to 7 cm) and very sharp. Then, one blade must be consistently rested along the edge of the knife gap and a slight sawing motion should be used to obtain a more consistent slice. The extra step of adjusting the angle and the training required to obtain repeatable sections from different steaks are drawbacks for the application of the angle adjustable box in an industrial environment (e.g. commercial abattoir). However, in a research environment, preparation of a single, angle adjusted slice may require less time than the multiple cores (normally 6-8) prepared for WBSF.

Before using the cutting box, there are a few steps that are important and more critical than others, such as the packaging of the samples. Fresh samples prior to cooking should be covered, preferably with a piece of plastic to prevent sample dehydration. Before vacuum packaged samples, the seal should be inspected to ensure the vacuum has not been broken, and resealed if necessary. Ageing time is one of the most important factors contributing to the variability in meat tenderness¹⁴ and must be considered in the design of experiments. Freezing the samples may be necessary, but frozen-thawed samples usually have lower shear force values than chilled meat¹⁵. After storage and prior to cooking, it is important that the temperature probes are inserted into the middle of the steaks, equidistant from the cooking surfaces. This will prevent the steak from rapidly cooking on one side, and then very slowly cooking on the other side. If the internal temperature appears to be changing at a different rate than other steaks (either too fast or too slow), reposition the probe to a more central position. Also, for temperature probe placement, attempt to avoid locations that are not representative of the whole steak, such as areas with fat or connective tissue deposits, thickness inconsistencies, or areas that appear to have muscle fibre separation.

Cooking procedures may also have a significant impact on final tenderness⁷. Thus, the proposed method, electric grill at 210 °C is a typical dry-heat method used to cook the samples. Using a double "clam grill" may reduce the cooking time, but the moisture loss may be greater due to the extra pressure from the top grill, leading to reduced tenderness. Another option is cooking for a fixed time, instead of to an endpoint temperature. Belt-grills and conveyor ovens can be used and they may easily be combined with the SSF protocol¹⁶. However, the thickness of the steaks needs to be controlled, as large variations in endpoint temperature may cause inconsistent tenderness values¹⁷. Due to the nature of working with a non-homogenous tissue such as meat, structural differences amongst the samples may result in different steak depths despite care and attention when cutting. Other authors use moist cooking, such as water bath methods¹⁸. This usually results in longer cooking times at lower temperatures, increasing the tenderness of meat with high connective tissue content⁷. Therefore, the cooking method utilized to prepare the meat prior to tenderness evaluation needs to be carefully chosen according to the type of meat and the goals of the experiment.

Finally, when analyzing the SSF of the sample, very different values can be obtained. Authors can find values from <10 kg in extremely tender meat with tenderness enhancement treatments or very long ageing periods, to >50 kg in samples with high collagen content, cold shortening or extremely short ageing periods. If tough samples are expected in an experiment, the load cell for the texture analyzer should be 100 kg instead of 50 kg, as reported in the present study, or values from very tough samples will not be accurately recorded. However, using load cells with higher peak values would result in reduced precision. If the goal is merely to classify tender and tough meat, the 50 kg load cell may be sufficient, as any sample over that value would be considered extremely tough.

Disclosures

We have nothing to disclose.

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