

# Consumer Thresholds for Establishing the Value of Beef Tenderness

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## Introduction

The focus on beef tenderness improvement by the research community and the beef industry has continued for a half century. Improving the quality and consistency of beef has been a major focus of many researchers and industry organizations during the past decade. Beef demand declined 23% from 1979 to 1990 (USDA, 1990), having been attributed to the lack of quality and consistency of beef tenderness and to the diet/health scare. The National Cattlemen's Beef Association has identified improvement in tenderness and reduction of the variability in tenderness as major issues facing the beef industry. During the past five years, the beef industry and research community have spent countless hours and dollars attempting to find the causes for variation in beef tenderness. In addition, many research studies have focused on possible solutions to meat tenderness problems.

Possible solutions to the tenderness problem are electrical stimulation (Savell et al., 1976), calcium chloride injection (Koochmaraie et al., 1989), and the tender cut (Ludwig et al., 1997). However, the need to research the factors responsible for the variation in beef tenderness and to focus on the consumer perceptions of beef tenderness has never been greater.

Tenderness is the most important factor influencing consumer satisfaction for beef palatability (Dikeman, 1987; Savell et al., 1987, 1989; Smith et al., 1987; Miller et al., 1995). The ability of consumers to segregate beef into varying tenderness levels is essential for establishing the value of beef tenderness. If consumers do not have the ability to determine differences in tenderness, then all efforts to improve the tenderness of beef are of little value. Thus, it is most important that the industry establish the consumers' ability to segregate beef of varying tenderness.

Assuming that consumers can detect differences in tenderness, then the need exists to measure and establish the value of tenderness to the marketplace (Boleman et al., 1997). Establishing values associated with varying degrees of beef tenderness will allow the economic incentive for the beef industry to search for, manage, and market tenderness to the consumer. The economic incentives for the industry to improve the tenderness of beef must be established before significant improvements in the consistency and palatability of beef will occur.

In this paper we will present some of the data that indicate the ability of consumers to segregate beef among varying ranges of tenderness and their ability to relate differences in tenderness to a value for the market place.

**Table 1. Important Criteria When Studying Consumer Perceptions of Beef**

Trait	Criterion
Tenderness range	Not all steaks are tough or tender to all consumers. WBS range should be <2.0 to >7.0 kg.
Tenderness distribution	All tenderness categories should be represented equally so that the target will not be skewed too high or too low
Consumer population	Consumers should be selected to represent many segments of light and heavy beef users
Steak sampling by consumers	Each consumer should evaluate the range of meat tenderness to establish a within-customer threshold for tender and tough meat.

## Important Factors When Studying Consumers' Perceptions of Beef Tenderness

Study of consumer perceptions of beef tenderness must first take into account some important factors (Table 1). The most important factor in a tenderness study with consumers is to establish that a range in beef tenderness from tender to tough exists. Obtaining this wide tenderness range is a very expensive process, but necessary to determine if the differences are of value. Many research studies have been published in which all of the meat was tender. It is

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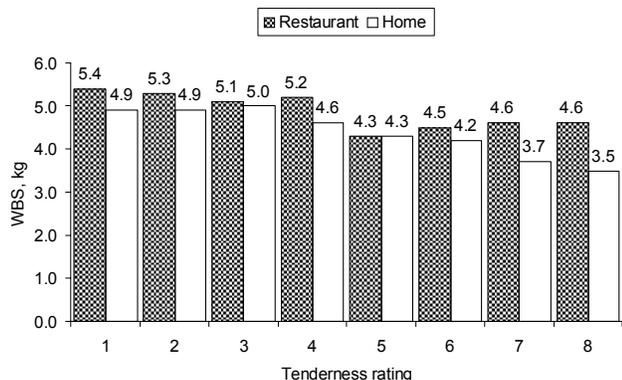
very difficult to study tenderness and the consumer perception of tenderness/toughness if all of the meat is similar. The fact that 10 to 25% of the beef steaks sold at retail stores are tough (Morgan et al., 1991; Savell et al., 1991) shows the importance of making sure that the meat used in beef tenderness consumer studies has sufficient variation to match beef currently sold. The opportunity to select meat for consumer tenderness studies that was mostly or all tender has lead to the publication of conclusions that may not be correct. Therefore, it is important to ensure that a wide range of tenderness is available for study before research is conducted.

Secondly, it is very important to ensure that the tenderness distribution is not skewed. Consumers should test equal amounts of tough and tender meat. The samples eaten by consumers in a study should be equally distributed between tough and tender meat.

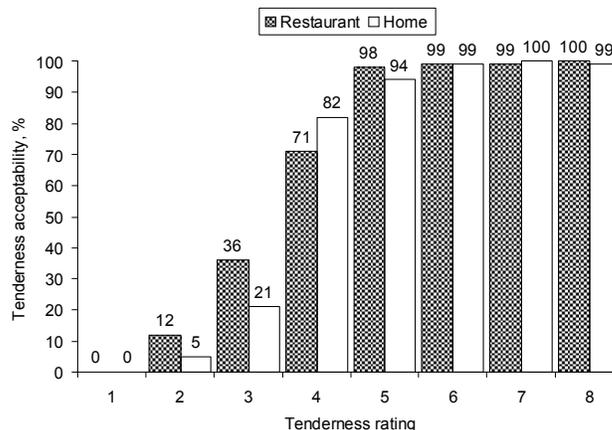
Consumer test subjects must represent beef consumers in the market place. A distribution of light to heavy beef consumers should be used and test subjects should represent variations in income, ethnicity, education and gender unless a specific market segment is the target for a specific product. Data from consumers who do not regularly consume beef are of little value when establishing a threshold for beef tenderness and its associated value.

Lastly, it is very important that each consumer serve as his/her own control by testing meat of varying tenderness. Wheeler et al. (1997) segregated beef into three tenderness categories - tender, intermediate, and tough. To determine the threshold for beef consumers, it is important for each consumer to eat beef from each category. Neely et al. (1998) utilized many of these criteria in selecting consumers and meat for their beef customer satisfaction study. In addition, Boleman et al. (1997), Huffman et al. (1996), Hoover et al. (1995), and Miller et al. (1995) used many of these factors and selection criteria in conducting their consumer research.

**Figure 1. Relationship of Warner-Bratzler shear force values to tenderness ratings of steaks by consumers in a restaurant and in homes. Values shown are means; n=62 consumers. From Miller et al. (1995).**



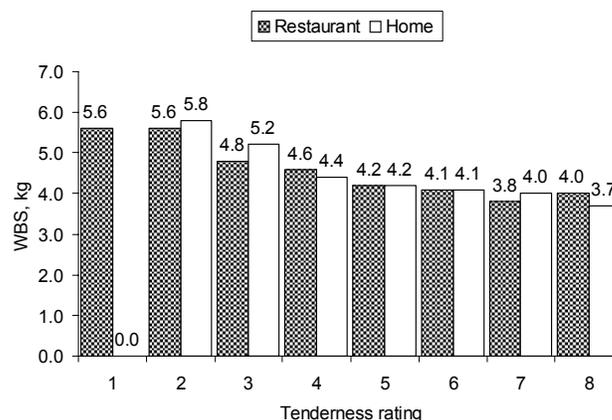
**Figure 2. Percentage of steaks at each tenderness rating determined acceptable in tenderness by consumers in a restaurant and in homes. From Miller et al. (1995).**



### Establishment of Consumer Thresholds for Beef Tenderness

Tenderness acceptability thresholds for beef have been studied extensively during the past five years. Shackelford et al. (1991) published the first threshold relating Warner-Bratzler shear (WBS) force values to consumer data by regressing trained sensory panel tenderness ratings on WBS data from a study by Smith et al. (1982). The first step in establishing a threshold for beef tenderness was the determination of whether consumers can differentiate among WBS values. Both Miller et al. (1995) and Huffman (1996) found that consumers could differentiate among steaks varying in WBS values. Data in Figures 1 and 2 (Miller et al., 1995) show that as WBS values decreased, tenderness scores increased, indicating that consumers (n = 62) could detect changes in tenderness similar to those found with instrumental measurements. Each consumer sampled steaks

**Figure 3. Warner-Bratzler shear force values by sensory tenderness ratings of steaks by consumers at home and in a restaurant. No consumers at home gave a 1 rating; n=90 consumers. From Huffman et al. (1996).**



**Figure 4. Percentage of steaks by sensory tenderness scores considered acceptable in tenderness by consumer panelists. No consumers at home gave a 1 rating. From Huffman et al. (1996).**

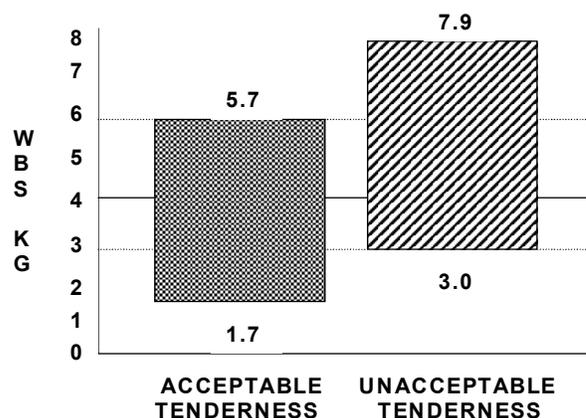


varying in WBS values from <2.0 to >8.4 kg. The steaks were obtained from four subprimal cuts obtained from the loin, rib, and round. The steaks from the center portion of each muscle were trimmed to the same size. Consumer acceptability of beef can be affected by changes in tenderness (figure 2). The ability of consumers to segregate beef steaks by relative differences in tenderness is an important finding for the beef industry and research community when establishing thresholds for assigning value to beef tenderness.

Huffman et al. (1996) determined consumer thresholds for beef steak tenderness in consumers' homes and in restaurants. Steaks were obtained from 320 beef loin strips (IMPS #180). A WBS value was determined on one steak from each strip. The steaks then were assigned to 90 consumers to evaluate in both home and restaurant environments. Each consumer evaluated steaks in both environments that ranged in WBS values from <1.7 to >7.9 kg. All steaks in the study were cooked to a medium degree of doneness. The results (figures 3 and 4) parallel those of Miller et al. (1995). As WBS value decreased, the tenderness score increased, showing that consumers in both the home and restaurant can determine tenderness levels similar to the WBS instrument. WBS values can be used to build a value relationship for beef tenderness. Acceptability of beef also changed as the WBS values shifted (figure 4). The data from these two studies show that the beef industry can establish levels of consumer acceptability for beef tenderness and relate those levels to an objective WBS force value.

Wheeler et al. (1997) indicated the best way to approach the establishment of tenderness thresholds was to establish multiple tenderness classes to allow retailers, foodservice operators, and consumers to select beef with a level of tenderness that met their expectations. We agree with this approach and believe that these classifications can be derived from the data reported by Miller et al. (1995)

**Figure 5. Range in Warner-Bratzler shear force for steaks consumers identified as unacceptable in tenderness and those identified as acceptable in tenderness. Adapted from Huffman et al. (1996).**



and Huffman et al. (1996). The data in figure 5 show tenderness threshold classes established from the data published by Huffman et al. (1996) and indicate that steaks can be grouped into three tenderness threshold classifications of <3.0 kg, 3.0 to 5.7 kg, and >5.7 kg WBS value. The consumer responses indicate the lowest shear force group would be 100% acceptable and the highest shear force group would be 100% unacceptable in tenderness. Therefore, the ability to segregate beef into tenderness groups and assign them a value according to their market relationship to the consumer exists.

Shackelford and co-workers Koohmaraie and Wheeler (1997 a, b) at the US Meat Animal Research Center have developed a rapid tenderness shear force methodology that will allow the beef industry to segment beef based on tenderness. The development of this rapid tenderness characterization can have a revolutionary impact on the way beef is priced and sold to both the retail and foodservice industries, if the value associated with tenderness can be characterized.

The studies of Miller et al. (1995) and Huffman et al. (1996) are a good attempt to classify beef into tenderness threshold classes by relating consumer acceptability data to WBS force values. However, these studies are limited in their application to all consumers because they tested a small sample of consumers who resided in one city. The need for additional consumer research in this area of Meat Science is greatly needed to establish tenderness thresholds that will meet the expectations of most beef consumers. Consumer research conducted by the National Cattlemen's Beef Association in partnership with researchers from Texas A & M and Colorado State Universities has contributed important information about consumer impressions of beef. These studies focused on the relationship of customer satisfaction to USDA quality grade, degree of doneness, the cut of beef, and the geographical location of the consumer (NLSMB, 1995; NCBA, 1997; Neely et al.,

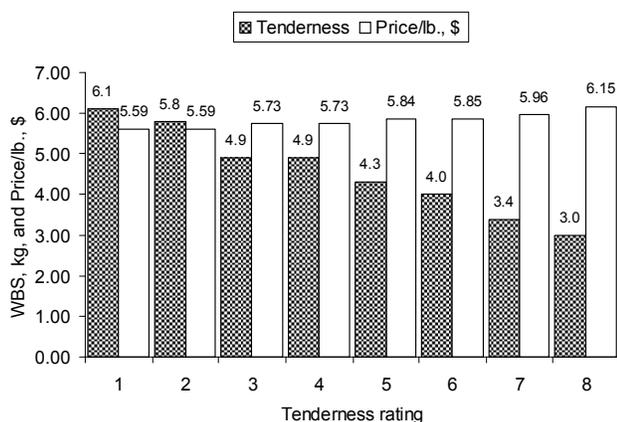
1998). Expanding this research area is vital if the beef industry hopes to establish tenderness thresholds for classifying beef into different value categories.

The need to build on the consumer data of Miller et al. (1995) and Huffman et al. (1996) by relating consumer preferences to WBS force in a larger group of consumers from different geographic locations led us to conduct a larger, nation-wide consumer research study (Miller et al., 1998). Beef was obtained from 1036 beef steers. The strip loins (IMPS #180) were fabricated into 2.5-cm-thick steaks. Representative steaks were evaluated for tenderness classification by WBS force and a trained sensory panel. The steaks were cooked on electric grills to medium rare, medium, and well done degrees of doneness to establish the tenderness of each steak prior to establishing the tenderness classifications to be used in the nation-wide consumer study. Six 1.3-cm-diameter cores were removed from each steak and sheared once parallel to the orientation of the muscle fibers with the WBS device (AMSA, 1995). The steaks used for the consumer study were classified as tender (WBS ranging from 1.62 to 2.29 kg), intermediate tenderness (3.92 to

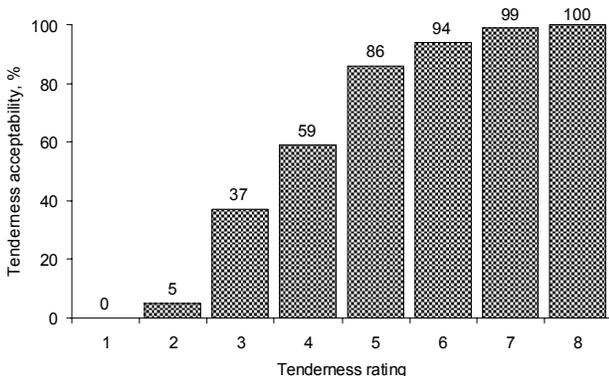
4.50 kg) and tough (5.42 to 7.42 kg). The steaks were identified according to their tenderness classification, vacuum packaged and frozen before shipment to each of five cities for consumer evaluations. The test sites were three supermarkets in each of five metropolitan areas representing a wide range of income, education and ethnicity for each location. The five metropolitan areas studied were 1. Baltimore, MD/Washington D.C., 2. Chicago, IL, 3. Dallas/Fort Worth, TX, 4. Los Angeles, CA, and 5. Lubbock, TX. Five research teams were trained on data collection procedures prior to collection of data during the same 10-day period. The teams cooked steaks at each location that were from the same strip loins to the same degree of doneness on the same day to reduce the variation that may occur among locations. A total of 734 consumers sampled two 1 x 1 x 1-cm cubes from each of three steaks in the three stores in each metropolitan area. Consumers were asked to evaluate samples from each tenderness classification for one degree of doneness (medium rare, medium or well done). Each consumer evaluated samples from steaks that had been classified as tender, intermediate and tough. About 7 minutes were required for each consumer to evaluate the samples.

The consumers in this study were 52% light beef users, 41% heavy beef users and 6% moderate beef users. The data from this study (figures 6 and 7) are similar to those reported by Miller et al. (1995) and Huffman et al. (1996). The consumers were able to segregate the beef into tenderness threshold groups. The consumers were able to differentiate among beef steaks from different WBS categories and could detect changes in tenderness similar to those found by the WBS instrument. The data among all three independently-collected consumer research studies agree and indicate that the beef tenderness classification system proposed by Shackelford et al. (1997 a, b) certainly is possible. The fact that consumers can determine differences in beef of varying WBS values suggests that the beef industry can set tenderness thresholds that will meet a high proportion of the consumer expectations for beef tenderness. The data in figure 7 also reflect that tenderness acceptability by consumers is altered as WBS force values change

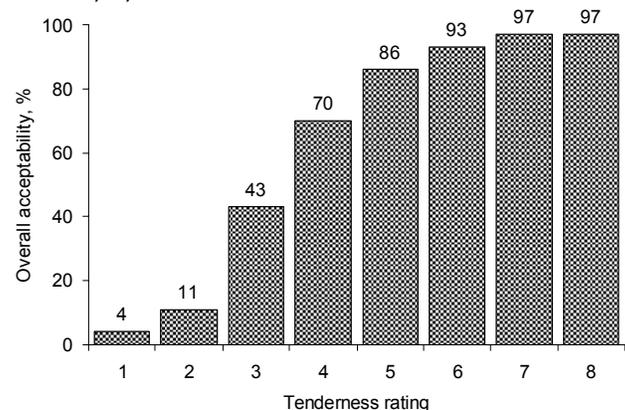
**Figure 6. Relationship of Warner-Bratzler shear force values to tenderness ratings and value price relationships of steaks by consumers (n=734 consumers).**



**Figure 7. Percentage of steaks at each tenderness rating acceptable in tenderness by consumers and value/price relationships (n=734).**



**Figure 8. Percentage of steaks rated acceptable in overall palatability by consumers (n=734).**



and that a high degree of consumer acceptability can be achieved in beef steaks with a lower WBS force. The transition from tender to tough beef occurred at 4.3 to 4.9 kg of WBS (figure 6) and the percentage of consumer acceptability for tenderness decreased from 86% at 4.3 kg for a slightly tender rating to 59% at 4.9 kg for a slightly tough rating. The ability of these consumers to differentiate the degree of tenderness in this precise fashion is very important for the beef industry and their attempt to implement a tenderness threshold classification system. Data presented in figures 6 and 7 show that a WBS threshold of <3.0 kg would result in 100% consumer acceptability for beef steak tenderness and that a WBS value of 3.4, 4.0 and 4.3 kg would result in 99, 94 and 86% customer satisfaction for tenderness, respectively. The data from this consumer research study show that the beef industry could apply the recommendation of Wheeler et al. (1997) in setting different tenderness threshold categories to meet different consumer tenderness expectations. Data from this consumer study suggest tenderness threshold classes of <3.0 kg, 3.0 to 4.8 kg and >4.9 kg and would result in 100%, 93% and 25% customer satisfaction for beef tenderness, respectively. An interesting finding in this study was that a high number of consumers rated slightly (59%) and moderately (37%) tough beef acceptable for tenderness. The overall acceptability ratings shown in figure 8 indicated a 70% consumer acceptance rate for slightly tough beef (4) and show that other factors may contribute to the consumer acceptability of beef. Miller et al. (1995) and Neely et al. (1998) reported that all consumers may not require the same tenderness in beef to be satisfied, and that either beef flavor or juiciness may influence their perception of tenderness and their overall acceptability ratings.

**Table 2. Percentages of Beef Top Loin Steaks Purchased by Consumers During Initial Purchase (Phase II) and Repurchase (Phase III)<sup>a</sup>**

Category	Phase II	Phase III
Red (Tender)	55.3 <sup>b</sup>	94.6 <sup>b</sup>
White (Intermediate)	12.6 <sup>c</sup>	3.6 <sup>c</sup>
Blue (Tough)	32.0 <sup>d</sup>	1.8 <sup>c</sup>

<sup>a</sup> Source: Boleman et al. (1997).

<sup>b,c,d</sup> Means in a column with different superscripts differ (P<.05).

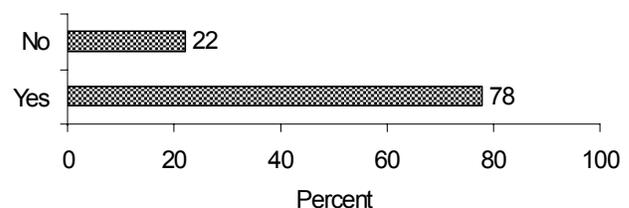
### Establishing the Value of Beef Tenderness

Establishing the value of beef tenderness is a difficult task. The only attempts to show the value of tenderness were reported by Boleman et al. (1997) and Miller et al. (1998). Table 2 shows the purchasing behavior of consumers when price was the only consideration (Phase II) and when price was related to the threshold of tenderness (Phase III). Consumers purchased more tender steaks at a higher price 94.6% of the time when given the opportunity to buy beef segregated into tenderness categories. Phase II con-

sumers were allowed to purchase steaks differing in price from a retail display case with no information regarding their tenderness. The cheapest steaks that also were the toughest were purchased by 32% of the consumers. During repurchasing in Phase III, tenderness and price of the steak were shown on each package. Only 1.8% of the consumers repurchased the tough steaks that were priced lower than the more tender steaks. The research of Boleman and coworkers clearly demonstrates the ability of consumers to discriminate among tenderness categories and their willingness to pay a premium for tender beef.

The study conducted by Boleman and coworkers is an excellent study, but a nation-wide study with larger numbers of consumers was needed to determine if the consumers' willingness to pay a premium for more tender beef was universal. The research by Miller et al. (1998) clearly established that consumers could differentiate between different tenderness levels. The ability of the beef industry to use these different tenderness thresholds and to assign different values that consumers are willing to pay is very important. We were interested in trying to determine the value associated with different tenderness thresholds while conducting the nation-wide consumer study reported by Miller et al. (1998). We asked each consumer if they would be willing to pay more for beef "guaranteed tender" by the retailer. Seventy-eight percent of the consumers said they would purchase steaks if the retailer (figure 9) guaranteed them to be tender. These findings support and agree with the findings of Boleman et al. (1997). Consumers are willing to pay a higher price for a more tender beef steak. We were still interested in determining a value associated with tender versus tough beef so we asked each consumer to choose a price they would be willing to pay for each steak they. Consumers were asked to choose paying \$ 7.79, \$6.49 or \$ 4.99/lb for each steak they evaluated. The average price for each steak was calculated and a value determined for each WBS force tenderness threshold category (figure 6). Steaks in the tender classification (100% tenderness acceptability rating, figure 7) having WBS values <3.0 kg had a value of \$6.15/lb assigned by consumers at retail (figure 6). The intermediate classification (93% tenderness acceptability rating, figure 7) had a WBS value ranging from >3.0 kg to <4.9kg and had a value of \$5.88/lb assigned by consumers at retail (figure 6). The tough classification had a WBS value >4.9 kg and had a value of \$5.66/lb. The lowest value (\$5.59/lb) given was for the steaks rated either a one or two tenderness rating (very or extremely tough, fig-

**Figure 9. Percentage of consumers willing to pay more per pound for a guaranteed tender steak at retail (n=734).**



ure 6). These two categories had only a 2.5% tenderness acceptability rating (figure 7). The value difference between the tender (<3.0 kg WBS) and intermediate classifications (>3.0 and <4.9 kg) is \$0.27/lb (figure 6). The difference between the tender and tough classifications (>4.8 kg) is \$0.49/lb. The value difference between the tender classification (<3.0 kg) and the toughest beef classification (>5.7 kg) is \$0.56/lb (figure 6). The consumers were able to reflect a value relationship among different tenderness threshold classifications. The \$0.56/lb (toughest), \$0.49/lb (tough) and \$0.27/lb (intermediate) retail value difference between the most tender the toughest, tough and intermediate beef tenderness threshold classifications would allow the beef industry to segment beef into different tenderness classifications. The retail steak value differences found in this study would result in the opportunity for a premium to be paid to a guaranteed tender (<3.0 kg WBS value) carcass of \$76.16 vs. the toughest (>5.7 kg) classification (figure 10). A premium of \$66.64 could be paid to the tender classification carcasses vs. the tough classification carcasses and a premium of \$36.72 could be paid for the tender classification carcasses vs. the intermediate classification carcasses. These data show that consumers can determine value differences of different beef tenderness threshold classifications and that the beef industry could implement a tenderness-based sorting system that reflects the value of tenderness to the consumer at retail.

**Figure 10. Calculations used to determine the value differences among tenderness thresholds for the assignment of value premiums to more tender beef carcasses**

- 750 lb. Carcass weight X 26% rib and loin yield = 195 lb. rib and loin.
- 195 lb. X 70% Yield of steaks from rib and loin = 136 lb. saleable steaks.
- \$6.15 - \$5.59 = \$0.56 difference in price between steaks with >5.8 kg WBS value (toughest) and tender steaks (<3.0 kg WBS value).
- \$6.15 - \$5.66 = \$0.49 difference in price between steaks with >4.9 kg WBS value (toughest) and tender steaks (<3.0 kg WBS value).
- \$6.15 - \$5.88 = \$0.27 difference in price between steaks from >3.4 to <4.8 kg WBS value (intermediate) and tender steaks (<3.0 kg WBS value).
- 136 lb. saleable retail steaks X \$0.56 = \$76.16 margin/carcass for tender vs. toughest steaks.
- 136 lb. X \$0.49 = \$66.64 margin/carcass for tender vs. tough steaks.
- 136 lb. X \$0.27 = \$36.72 margin/carcass for tender vs. intermediate steaks.

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