# Tenderness Classification of Beef: IV. Effect of USDA Quality Grade on the Palatability of "Tender" Beef Longissimus When Cooked Well Done[1]

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**ABSTRACT:** The objective of this experiment was to determine the impact of USDA quality grade on the palatability of "tender" longissimus when cooked well done. Warner-Bratzler shear force was determined on longissimus thoracis steaks aged 3 or 14 d postmortem (cooked to 70°C) from carcasses of 692 steers and heifers. Steaks from 31 carcasses with Modest or Moderate marbling scores (Top Choice) and steaks from 31 carcasses with $Slight^{00}$ to $Slight^{40}$ marbling scores (Low Select) were selected for this experiment from carcasses identified as "tender" (shear force < 5.0 kg at 3 d postmortem). Longissimus thoracis steaks with 3 or 14 d of postmortem aging were cooked to 80°C and evaluated by a trained sensory descriptive attribute panel. Top Choice steaks had higher ($P < .05$) juiciness (5.8 vs 5.3) and beef flavor intensity ratings (4.9 vs 4.6) than Low Select steaks. Aging of steaks for 14, rather than 3, d postmortem improved ($P < .05$) beef flavor intensity rating (4.8 vs 4.7) but not ($P > .05$) juiciness rating (5.6 vs 5.5). The interaction ($P < .05$) of quality grade and aging time for tenderness rating indicated that Top Choice steaks were more tender ($P < .05$) with 3 d of aging than steaks from Low Select carcasses (6.3 vs 5.8), but steaks from Top Choice and Low Select carcasses had similar ($P > .05$) tenderness ratings after 14 d of aging (7.0 and 6.8). Compared to palatability of steaks from Low Select carcasses, the palatability of steaks from Top Choice carcasses was less affected by elevated degree of doneness in "tender" longissimus thoracis, especially when steaks were aged for only 3 d. Although differences in sensory traits between Top Choice and Low Select steaks were small, the consumers who cook beef well done may benefit from implementation of tenderness classification in conjunction with USDA quality grade.

Key Words: Beef, Classification, Cooking, Grading, Quality, Tenderness

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## Introduction

Industry leaders (NCA, 1994b) have suggested that sorting of beef based on tenderness would increase consumer satisfaction by enabling the industry to manage and reduce variations in tenderness. This suggestion has been supported by the report of Boleman et al. (1997), who noted that consumers were willing to pay more for "tender" meat. The recent development of technology to accurately sort beef carcasses based on meat tenderness (Shackelford et al., 1997, 1999) will enable the beef industry to further evaluate that suggestion.

Tenderness decreases as degree of doneness increases (Cover et al., 1962; Parrish et al., 1973; Cross et al., 1976), and 64% (Branson et al., 1986) or 82% (NLSMB, 1995) of beef consumers cook meat medium to very well done. However, the detrimental effects of elevated degree of doneness on tenderness were much greater in less tender than in more tender longissimus (Wheeler et al., 1999). In addition, it has been hypothesized (Smith and Carpenter, 1974; Savell and Cross, 1988) that steaks from carcasses of lower quality grades are more affected by elevated degree of doneness than are steaks of higher quality grades, although convincing evidence for such a relationship is lacking (Parrish et al., 1973; NLSMB, 1995). Thus, it is unclear whether tenderness classification, used in conjunction with USDA quality grades, would improve

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[3]Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.

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differentiation in palatability compared to use of tenderness classification alone. The objective of this experiment was to determine the impact of USDA quality grade and aging time on the palatability of “tender” longissimus when steaks were cooked well done.

## Materials and Methods

*Animals.* The Roman L. Hruska U.S. Meat Animal Research Center (**MARC**) Animal Care and Use Committee approved the use of animals in this study. Crossbred steers and heifers (n = 692) were weaned at approximately 200 d of age, fed a corn and corn silage diet for 215 to 313 d, and slaughtered serially in nine groups during a period spanning 98 d. Animals were slaughtered and processed at a commercial packing plant. At 36 h postmortem, carcasses were ribbed between the 12th and 13th ribs, and USDA quality and yield grade factors were measured by experienced MARC personnel (USDA, 1997). The wholesale rib was obtained from the right side of each carcass and transported to MARC.

*Assignment of Steaks.* At 3 d postmortem, the ribeye roll (IMPS #112; longissimus thoracis) was removed from each rib. A 15.2-cm-long section was removed from the posterior end of the ribeye roll, vacuum-packaged, aged (2°C) until 14 d postmortem, and frozen (−30°C) for later measurement of Warner-Bratzler shear force and trained sensory descriptive attribute panel evaluation. The remainder of the ribeye roll was vacuum-packaged and immediately frozen (−30°C) for later measurement of Warner-Bratzler shear force and trained sensory descriptive attribute panel evaluation.

Using a band saw, each of the two frozen ribeye roll sections was sliced to yield four steaks (2.54 cm thick). Beginning at the caudal end of the ribeye roll, steaks were numbered 1 through 8. Steaks 1 through 4 came from the section that was frozen at 14 d postmortem, and steaks 5 through 8 came from the section that was frozen at 3 d postmortem. Steaks 1 and 7 were used for assessment of Warner-Bratzler shear force at 3 and 14 d postmortem, respectively.

*Warner-Bratzler Shear Force.* Steaks were thawed (5°C) until an internal temperature of 5°C was reached, then they were cooked with a belt grill (model TBG-60 Magigrill, MagiKitch’n Inc., Quakertown, PA). Belt grill settings (top heat = 163°C, bottom heat = 163°C, preheat = disconnected, height [gap between the platens] = 21.6 mm, and cook time = 5.7 min) were designed to achieve a final internal temperature of 70°C for 2.54-cm-thick steaks (Wheeler et al., 1998). After the steaks exited the belt grill, a needle thermocouple was inserted into the geometric center of the steak and postcooking temperature rise was monitored with a hand-held thermometer (Cole-Parmer, Vernon Hills, IL). The maximum temperature, which occurred approximately 2 min after the steak exited the belt grill, was recorded as the final cooked internal temperature. Warner-Bratzler shear force was measured on the cooked steaks as described by AMSA (1995) with the following details. The cooked steaks were chilled 24 h at 3°C, then six cores 1.27 cm in diameter were removed parallel to the muscle fiber. Each core was sheared once on an Instron Universal Testing Machine (model 4411, Instron, Canton, MA) with a Warner-Bratzler attachment using a 200 mm/min crosshead speed.

*Selection of Subsample.* Ribs were selected for inclusion in this experiment based on tenderness classification and quality grade. Ribs with a longissimus thoracis Warner-Bratzler shear force value less than 5 kg at 3 d postmortem were classified as “tender.” Based on regression analyses, a Warner-Bratzler shear force value of 5 kg is equivalent to the 23 kg of slice shear force used by Shackelford et al. (1999) to identify “tender” longissimus. Longissimus steaks from all of the “tender,” Top Choice (marbling score of Modest or Moderate) ribs (n = 31) and a random subsample (n = 31) of the “tender,” Low Select ribs were evaluated by a trained sensory descriptive attribute panel.

*Trained Sensory Panel Analysis.* Steaks 3 and 4 were used for sensory panel evaluation of steaks aged 14 d postmortem, and steaks 5 and 6 were used for sensory panel evaluation of steaks aged 3 d postmortem. Steaks for sensory panel analysis were thawed and cooked as described above, with the exception that the cooking time was increased to 7.8 min to achieve a final internal cooked temperature of 80°C (the range in final cooked temperature was 76.1 to 87.0°C). Steaks were cut and served immediately after cooking. Each panelist received three cubes (1.3 cm × 1.3 cm × cooked steak thickness) from each sample. Sensory panelists scored steaks for tenderness, juiciness, and beef flavor intensity on 8-point scales (1 = extremely tough, dry, or bland and 8 = extremely tender, juicy, or intense). The eight-member sensory panel was selected and trained according to procedures described by Cross et al. (1978) and was highly experienced.

*Statistical Analysis.* Data were analyzed by analysis of variance for a split-plot design (SAS, 1989). The whole-plot treatment was quality grade and the split-plot treatment was aging time. The error term for the whole plot was animal × quality grade, and the error term for the split-plot was the residual error.

## Results

Top Choice carcasses were fatter than Low Select carcasses but had similar longissimus areas, and, thus, higher numerical yield grades (Table 1). The main effect of quality grade ($P = .27$) and the quality grade × aging time interaction ($P = .25$) were not significant for Warner-Bratzler shear force when steaks were cooked to 70°C (Table 2). However, an

Table 1. Carcass traits for the main effect of USDA quality grade for carcasses with “tender” longissimus[a]

| Quality grade | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| Top Choice (n = 31) | | | | |
| Hot carcass weight, kg | 317.3 | 35.6 | 241.8 | 388.7 |
| Adj. fat thickness, cm | 1.17 | .25 | .51 | 1.78 |
| Longissimus area, $cm^2$ | 77.5 | 10.0 | 63.8 | 104.4 |
| Kidney, pelvic, and heart fat, % | 3.5 | .5 | 2.5 | 4.5 |
| USDA yield grade | 3.1 | .7 | 1.9 | 4.3 |
| Marbling score[b] | 662 | 49 | 610 | 790 |
| Low Select (n = 31) | | | | |
| Hot carcass weight, kg | 299.4 | 45.1 | 228.2 | 384.2 |
| Adj. fat thickness, cm | .53 | .28 | .13 | 1.14 |
| Longissimus area, $cm^2$ | 78.1 | 11.9 | 52.5 | 102.5 |
| Kidney, pelvic, and heart fat, % | 2.5 | .6 | 1.0 | 3.5 |
| USDA yield grade | 2.0 | .7 | .7 | 3.6 |
| Marbling score[b] | 425 | 14 | 400 | 440 |

[a]“Tender” = < 5.0 kg Warner-Bratzler shear force at 3 d postmortem.
[b]400 = Slight$^{00}$, 600 = Modest$^{00}$.

aging time of 14 d decreased ($P < .01$) Warner-Bratzler shear force compared to an aging time of 3 d. Thus, the inherent tenderness (mean, variation, range) of steaks from both quality grades was very similar (Table 2). This similarity in tenderness between quality grades occurred even though longissimus steaks from carcasses were selected to meet the criteria for “tender” meat (3 d Warner-Bratzler shear force < 5.0 kg when cooked to 70°C), not specifically selected to be the same in tenderness.

When cooked well done (80°C), longissimus steaks from Top Choice carcasses tended to have higher ($P = .05$) tenderness ratings and had higher ($P = .01$) juiciness and beef flavor intensity ratings than those from Low Select carcasses (Table 3). Furthermore, the percentage of ratings ≤ 5.0 was the same for steaks of the two quality grades for tenderness, but it was higher for Low Select steaks than for Top Choice steaks for both juiciness and beef flavor intensity. Aging longissimus steaks for 14 d, compared to 3 d of postmortem aging at 2°C, increased ($P = .01$) tenderness and beef flavor intensity ratings and decreased the percentage of those ratings ≤ 5.0. However, juiciness ratings were not affected ($P = .47$) by quality grade. A significant interaction ($P = .04$) of quality grade × aging time was detected for trained

Table 2. Effects of USDA quality grade and aging time on Warner-Bratzler shear force of longissimus selected to be “tender”[a]

| Item | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| Quality grade | | | | |
| Top Choice (n = 62) | 3.7 | .56 | 2.42 | 4.97 |
| Low Select (n = 62) | 3.8 | .49 | 2.40 | 4.99 |
| $P > F$ | .27 | | | |
| Aging time | | | | |
| 3 d (n = 62) | 4.2 | .52 | 3.07 | 4.99 |
| 14 d (n = 62) | 3.3 | .55 | 2.40 | 4.93 |
| $P > F$ | .01 | | | |
| Pooled SEM | .05 | | | |
| Interaction | | | | |
| Top Choice | | | | |
| 3 d (n = 31) | 4.1 | .54 | 3.11 | 4.97 |
| 14 d (n = 31) | 3.3 | .58 | 2.42 | 4.93 |
| Low Select | | | | |
| 3 d (n = 31) | 4.3 | .47 | 3.07 | 4.99 |
| 14 d (n = 31) | 3.4 | .51 | 2.40 | 4.79 |
| $P > F$ | .25 | | | |
| Pooled SEM | .07 | | | |

[a]“Tender” = < 5.0 kg Warner-Bratzler shear force at 3 d postmortem. No attempt was made to select carcasses such that steaks of both quality grades would be equal in 3-d shear force.

Table 3. Effects of USDA quality grade and aging time on trained sensory panel traits of "tender" longissimus cooked well done[a]

| | Tenderness[b] | | Juiciness[b] | | Beef flavor intensity[b] | |
|---|---|---|---|---|---|---|
| Item | Mean | % ≤ 5 | Mean | % ≤ 5 | Mean | % ≤ 5 |
| Quality grade | | | | | | |
| Top Choice (n = 62) | 6.6 | 4.9 | 5.8 | .0 | 4.9 | 59.7 |
| Low Select (n = 62) | 6.3 | 4.9 | 5.3 | 21.0 | 4.6 | 85.5 |
| *P* > F | .05 | | .01 | | .01 | |
| Aging time | | | | | | |
| 3 d (n = 62) | 6.0 | 9.7 | 5.5 | 8.1 | 4.7 | 80.6 |
| 14 d (n = 62) | 6.9 | .0 | 5.6 | 14.5 | 4.8 | 64.5 |
| *P* > F | .01 | | .47 | | .01 | |
| Pooled SEM | .06 | | .03 | | .04 | |
| Interaction | | | | | | |
| Top Choice | | | | | | |
| 3 d (n = 31) | 6.3[d] | 9.7 | 5.8 | .0 | 4.8 | 71.0 |
| 14 d (n = 31) | 7.0[c] | .0 | 5.8 | .0 | 5.0 | 48.4 |
| Low Select | | | | | | |
| 3 d (n = 31) | 5.8[e] | 9.7 | 5.3 | 16.1 | 4.5 | 90.3 |
| 14 d (n = 31) | 6.8[c] | .0 | 5.3 | 29.0 | 4.6 | 80.6 |
| *P* > F | .04 | | .51 | | .46 | |
| Pooled SEM | .09 | | .05 | | .05 | |

[a]"Tender" = < 5.0 kg Warner-Bratzler shear force at 3 d postmortem. No attempt was made to select carcasses such that steaks of both quality grades would be equal in 3-d shear force.
[b]8 = Extremely tender, juicy, intense; 1 = extremely tough, dry, bland.
[c,d,e]Means in a column lacking a common superscript differ ($P < .05$).

sensory tenderness ratings of longissimus steaks (Table 3), indicating that if longissimus steaks were aged 14 d postmortem, there was no difference ($P > .05$) in tenderness ratings between Top Choice and Low Select longissimus. However, if aged only 3 d postmortem, tenderness ratings for Top Choice steaks were higher ($P < .05$) than those for Low Select steaks. This interaction was not apparent in the percentage of tenderness ratings ≤ 5.0. No interaction between quality grade and aging time was detected for juiciness ($P = .51$) or beef flavor intensity ratings ($P = .46$).

Table 4. Effects of USDA quality grade and aging time on average thawing and cooking traits of "tender" longissimus[a]

| Item | Thawing losses, % | SD | Cooking losses, % | SD | Initial temperature, °C | SD | Cooked temperature, °C | SD |
|---|---|---|---|---|---|---|---|---|
| Quality grade | | | | | | | | |
| Top Choice (n = 62) | 2.1 | .9 | 22.5 | 1.3 | 5.6 | .6 | 80.0 | 1.9 |
| Low Select (n = 62) | 3.3 | .9 | 24.4 | 1.1 | 5.6 | .6 | 80.7 | 1.4 |
| *P* > F | .01 | | .01 | | .95 | | .06 | |
| Aging time | | | | | | | | |
| 3 d (n = 62) | 3.1 | .9 | 23.6 | 1.2 | 5.6 | .6 | 80.4 | 1.6 |
| 14 d (n = 62) | 2.4 | .8 | 23.3 | 1.2 | 5.6 | .6 | 80.3 | 1.6 |
| *P* > F | .01 | | .06 | | .17 | | .57 | |
| Pooled SEM | .09 | | .11 | | .02 | | .14 | |
| Interaction | | | | | | | | |
| Top Choice | | | | | | | | |
| 3 d (n = 31) | 2.3 | .9 | 22.7 | 1.2 | 5.6 | .6 | 79.9 | 2.1 |
| 14 d (n = 31) | 1.8 | .8 | 22.4 | 1.4 | 5.6 | .6 | 80.1 | 1.7 |
| Low Select | | | | | | | | |
| 3 d (n = 31) | 3.8 | 1.0 | 24.5 | 1.1 | 5.6 | .7 | 80.9 | 1.2 |
| 14 d (n = 31) | 2.9 | .7 | 24.3 | 1.0 | 5.6 | .6 | 80.5 | 1.5 |
| *P* > F | .07 | | .70 | | .58 | | .18 | |
| Pooled SEM | .13 | | .16 | | .03 | | .20 | |

[a]"Tender" = < 5.0 kg Warner-Bratzler shear force at 3 d postmortem.

Thawing and cooking losses were higher ($P = .01$) for Low Select than for Top Choice longissimus steaks (Table 4). Initial and cooked temperatures were not different ($P > .05$) between steaks from the two quality grades. Increasing aging time from 3 to 14 d resulted in greater ($P = .01$) thawing losses, but it did not affect ($P > .05$) other thawing or cooking traits (Table 4). The interaction of quality grade × aging time was not significant ($P > .05$) for any thawing or cooking trait. The increased thawing and cooking losses may have contributed to the decreased sensory traits of Low Select longissimus relative to Top Choice. The targeted cooking end point of 80°C was achieved, but longissimus steaks from Low Select carcasses tended ($P = .06$) to reach a slightly higher cooked temperature than longissimus steaks from Top Choice carcasses (Table 4).

## Discussion

The USDA quality grades for beef (USDA, 1997) are intended to segregate beef carcasses into groups differing in palatability. Although there is a small, positive relationship between consumer satisfaction and quality grades (Savell et al., 1987; NLSMB, 1995), there also is evidence that quality grades do not adequately differentiate beef based on tenderness (Blumer, 1963; Parrish, 1974; Wheeler et al., 1994; George et al., 1997; Wulf et al., 1997). Thus, an unacceptably high degree of consumer dissatisfaction with beef eating quality occurs (Smith et al., 1992; NCA, 1994b). To remedy this situation, the beef industry has made the development of an accurate instrument for meat tenderness measurement a high priority (NCA, 1994a, 1995). Industry leaders (NCA, 1994b) have suggested that sorting beef based on tenderness would result in increased consumer satisfaction with beef by enabling the industry to manage and reduce the variation in tenderness. The recent development of a system for this purpose, based on modifications to Warner-Bratzler shear force (Shackelford et al., 1997, 1999), raises questions about how to most effectively use the tenderness information that could be available. The implementation of tenderness classification of beef in commercial practice could be independent of USDA quality grade or in conjunction with USDA quality grade.

Tenderness declines as degree of doneness increases (Cover et al., 1962; Parrish et al., 1973; Cross et al., 1976; Wulf et al., 1996). Furthermore, 82% of consumers cook their meat to at least a medium degree of doneness (NLSMB, 1995). The “insurance theory” of marbling proposes (Smith and Carpenter, 1974; Savell and Cross, 1988) that the palatability of longissimus with lower levels of marbling is more affected by elevated degree of doneness than is that of longissimus with higher levels of marbling, although convincing evidence is lacking (Parrish et al., 1973; Akinwunmi et al., 1993; NLSMB, 1995). Wheeler et al. (1999) have shown that the detrimental effects on tenderness of elevated degrees of doneness are lower in “more tender” than in “less tender” longissimus. In fact, the advantage in Warner-Bratzler shear force of “tender” compared to “commodity” (all 100 animals in that study) meat increased as degree of doneness increased, such that when cooked to 80°C, “commodity” meat was six times more likely than “tender” meat to have a shear force ≥ 5 kg (24 vs 4%) (Wheeler et al., 1999). Thus, in order to determine the most appropriate use of tenderness classification, the “insurance theory” of marbling was tested on “tender” longissimus.

We defined longissimus steaks from Top Choice and Low Select carcasses as “tender” if their 3-d Warner-Bratzler shear force was < 5.0 kg when cooked to 70°C, because this value is equivalent to the 23 kg of slice shear force that Shackelford et al. (1999) used to test the efficacy of tenderness classification. We do not know whether this criterion for “tender” longissimus would influence consumers’ satisfaction, but it was used as a starting point until more definitive consumer data become available. The definition of “tender” also depends on whether 100% acceptability is required for “tender” meat. Huffman et al. (1996) reported that longissimus with < 4.1 kg of Warner-Bratzler shear force (cooked to medium degree of doneness) would be acceptable to 98% of consumers. Wheeler et al. (1997) calculated from the data of Huffman et al. (1996) that in order to achieve 100% acceptability to consumers, an upper threshold of 3.0 kg for longissimus shear force would be required. However, use of this same threshold by others depends on conducting Warner-Bratzler shear force measurement the same way that Huffman et al. (1996) did. Wheeler et al. (1999) reported that it was possible to identify a small class of carcasses (10%) that would have 100% < 5 kg Warner-Bratzler shear force value if aged only 3 d and cooked well done.

Although the differences between Top Choice and Low Select steaks were very small, the results of the trained sensory panel evaluation of “tender” longissimus cooked to 80°C tended to support the “insurance theory” of marbling. Regardless of aging time, both juiciness (.5 units) and beef flavor intensity (.3 units) were rated lower in longissimus from Low Select than in longissimus from Top Choice carcasses. Furthermore, if aged only 3 d, longissimus from Low Select carcasses also was rated lower in tenderness (.5 units) than longissimus from Top Choice carcasses. It is not known whether the magnitude of these differences (.3 to .5 units on an 8-point sensory scale) is great enough to be detectable by consumers, but the differences imply that the palatability of “tender” longissimus cooked well done would be lower for Low Select than for Top Choice steaks.

To our knowledge, there are only limited data in the literature testing the interaction of degree of doneness and marbling (Gilpin et al., 1965; Parrish et al., 1973; Akinwunmi et al., 1993) and no data specifically testing “tender” meat for this interaction. Parrish et al. (1973) and Akinwunmi et al. (1993) reported that neither the main effect of marbling degree nor the interaction between marbling degree and internal cooked temperature was significant for Warner-Bratzler shear force or trained sensory panel tenderness, juiciness, or flavor in longissimus. However, Gilpin et al. (1965) indicated that the difference in tenderness ratings for “high” marbling longissimus relative to “low” marbling longissimus increased as degree of doneness increased. The data from NLSMB (1995) could be considered a test of the interaction of degree of doneness and quality grade in “tender” meat because the mean Warner-Bratzler shear force of longissimus cooked to 71°C was 2.68 kg. Thus, the longissimus steaks from NLSMB (1995) were even more tender than those from the current study (assuming comparable Warner-Bratzler shear force values between the two institutions). They (NLSMB, 1995) reported that consumers gave longissimus steaks from Top Choice carcasses higher “overall like” ratings than steaks from Low Select carcasses (.5 units on a 23-point scale) when cooked with numerous methods and to various degrees of doneness. However, NLSMB (1995) did not detect an interaction between degree of doneness and quality grade for consumer “overall like” ratings, indicating higher quality grade did not reduce the negative effects of increased degree of doneness.

Given the high proportion of U.S. consumers cooking beef steaks to elevated degrees of doneness (Branson et al., 1986; NLSMB, 1995), if the palatability differences in Table 3 are determined to be meaningful to consumers, then perhaps the shear force threshold identifying “tender” longissimus should be lower to offset degree of doneness effects. This would provide additional confidence that meat identified as “tender” would still be tender even when cooked to an elevated degree of doneness. Furthermore, tenderness classification may need to be implemented in conjunction with USDA quality grade to provide additional assurance that meat cooked well done would be desirable in tenderness, juiciness, and flavor.

## Implications

Tenderness classification of beef may need to be implemented in conjunction with use of USDA quality grade in order to ensure desirable longissimus palatability to consumers who cook beef well done.

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