IRIS AperTO

UNIVERSITÀ DEGLI STUDI DI TORINO

AperTO - Archivio Istituzionale Open Access dell'Università di Torino

Relationship between beef consumer tenderness perception and Warner-Bratzler shear force

This is the author's manuscript

Original Citation:

Availability:

This version is available http://hdl.handle.net/2318/101563 since

Terms of use:

Open Access

Anyone can freely access the full text of works made available as "Open Access". Works made available under a Creative Commons license can be used according to the terms and conditions of said license. Use of all other works requires consent of the right holder (author or publisher) if not exempted from copyright protection by the applicable law.

(Article begins on next page)

10 September 2026

UNIVERSITÀ DEGLI STUDI DI TORINO

This Accepted Author Manuscript (AAM) is copyrighted and published by Elsevier. It is posted here by agreement between Elsevier and the University of Turin. Changes resulting from the publishing process - such as editing, corrections, structural formatting, and other quality control mechanisms - may not be reflected in this version of the text. The definitive version of the text was subsequently published in: **Meat Science, 78 (2008) 153–156.** www.elsevier.com/locate/meatsci

You may download, copy and otherwise use the AAM for non-commercial purposes provided that your license is limited by the following restrictions:

(1) You may use this AAM for non-commercial purposes only under the terms of the CC-BY-NC-ND license.

(2) The integrity of the work and identification of the author, copyright owner, and publisher must be preserved in any copy.

(3) You must attribute this AAM in the following format: Creative Commons BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/deed.en), [http://dx.doi.org/10.1016/j.meatsci.2007.05.031]

Relationship between beef consumer tenderness perception and Warner–Bratzler shear force

G. Destefanis, A. Brugiapaglia, M.T. Barge, E. Dal Molin

Department of Animal Science, University of Torino, Via L. da Vinci 44, 10095 Grugliasco, Torino, Italy

Abstract

The aim of this study was to determine consumer ability to discern different levels of beef tenderness established by Warner–Bratzler shear (WBs). A panel of 220 people evaluated 60 samples of longissimus thoracis using a 5-point intensity scale (1: very tough; 5: very tender). Samples differed for commercial category, breed of animals and ageing length of meat. Shear force was measured by Instron equipped with a Warner–Bratzler device on 1.27 cm diameter cores. Correlation coefficient of WBs measurements with tenderness sensory ratings was _0.72. WBs value corresponding to class 3 of the sensory tenderness was 47.77 N. From this value, the range of WBs (22.96–72.59 N) was split into five categories to which connect the five classes of sensory tenderness. The results suggest consumers' difficulty in discriminating category 1 (WBs > 62.59 N) from category 2 (WBs: 52.78–62.59 N) and a greater inclination to distinguish category 5 (WBs < 32.96 N). As WBs category boundaries were probably too restrictive for the panel's selective ability, WBs scale was reduced to 3 categories by joining the two extreme categories (i.e. category 2 with 1 and category 4 with 5). In this case, 55.6% of consumers significantly discriminated tough from intermediate and tender meat and 62.3% distinguished tender from intermediate and tough meat ($P < 0.01$). Hence, WBs values >52.68 N and <42.87 N allow classification of tough and tender beef in a sufficiently reliable way.

Introduction

As emphasized by many Authors, tenderness is considered the most important qualitative characteristic of meat. According to Boleman et al. (1995) and Miller, Carr, Ramsey, Crockett, and Hoover (2001), the consumer would be willing to pay a higher price in the marketplace for beef as long as it is guaranteed tender. Unfortunately, tenderness is also a highly variable characteristic, depending on many intrinsic and extrinsic factors of the animal and on their interaction. This wide variability is a limiting factor for consumer product acceptability, besides being a reason for consumer dissatisfaction and reduction in beef consumption. Therefore, tenderness inconsistency is a priority issue for the meat industry (Koohmaraie, 1996). Tenderness can be evaluated by objective methods, instrumental or sensorial with trained panels, or by subjective methods, with a consumer panel (AMSA, 1995). Objective methods allow the comparison of different treatments as well as ascertaining their effect on a particular characteristic, but do not provide information concerning product acceptability or preference for

one kind of meat over another (Wheeler, Shackelford, & Koohmaraie, 1997). Therefore, consumer opinion is a key factor to establish meat value and justify purchase decision. Sensory methods, either analytical or affective, are expensive, difficult to organize and time consuming (Platter et al., 2003). Therefore, there have been many attempts to devise instrumental methods of assessing the force in shearing, penetrating, biting, mincing, compressing and stretching the meat whose results are a prediction of tenderness ratings obtained by taste panel (Lawrie & Ledward, 2006). The most widely used method is the single blade shear test of the Warner–Bratzler type (Culioli, 1995). Correlations of Warner–Bratzler shear with sensory assessment of beef tenderness are variable, with r values ranging from -0.32 to -0.94 (Caine, Aalhus, Best, Dugan, & Jeremiah, 2003). This variability depends on many factors, such as muscle type, sample preparation, cooking method, shear apparatus, measurement procedure and panel type. According to Risvik (1995), there is a fundamental difference in sensory evaluation performed by trained or consumer panel. In the first case the attention is focused on meat as an object of scientific research, while the consumer reacts very differently, mainly focusing on how meat can contribute to his/her personal satisfaction. According to Wheeler et al. (1997), there is insufficient data on the relationship between instrumental measurements of tenderness and consumer tenderness perception. Therefore, the aim of this research is to study consumer ability to discern different levels of tenderness indirectly established by Warner–Bratzler shear force.

Materials and methods

2.1. Sample preparation

Thirty samples of longissimus thoracis were taken 24 h post mortem between the 8th and 13th thoracic vertebra from the right side of cattle of the most widespread commercial categories in Italy, i.e. veal calves (n = 10) and young bulls (n = 20). The latter included dairy (n = 10) and beef (n = 10) breeds. Samples were immediately transferred to the laboratory, where they were further divided into two subsamples (for a total of 60 samples), vacuum packaged and aged for 4 or 8 d at 2°C. This procedure was only used in order to provide a wider range in tenderness, and so meat origin and ageing length were not considered in the statistical analysis. At the end of the pre-established ageing period, each subsample was frozen and stored at -25°C until utilization. The meat was thawed in a cooler at 2 _C for 24 h and then cooked by roasting in an electric convection oven, preheated at 210°C, until a final internal temperature of 70°C was reached. Cooking temperature was monitored by an iron/constantan thermocouple wire connected to a thermometer and inserted into the geometric centre of the sample. After discarding a cranial and caudal thin layer of meat, a 1.9 cm thick steak was employed for sensory analysis, while the remaining portion (3 cm thick) was used for shear force measurement.

2.2. Sensory evaluation

Tenderness sensory evaluation was performed under controlled conditions by a consumer panel of 220 people differing for sex, age and ethnic backgrounds (Destefanis, Brugiapaglia, Barge, Barge, & Omento, 2004). In each session, the panelist evaluated 3 samples, selected considering animal category and ageing length. On average, each sample was evaluated by 10 panelists. The steaks, trimmed of external browned surface and labelled with three digit random numbers, were cut into 1.3 x 1.3 x 1.9 cm cubes and presented hot to the panelists. Subsequent samples were tested at intervals of about four minutes. Each consumer was involved in only one session. Tenderness sensory evaluation was carried out using a 5-point intensity scale, anchored at the end by the words ‘‘very tough’’/‘‘very tender’’ (AMSA, 1995; Cross, Durland, & Seideman, 1986). The scale was: 1 = very tough; 2 = tough; 3 = intermediate; 4 = tender; 5 = very tender.

2.3. Warner–Bratzler shear force (WBs)

After cooking, steaks for shear force determination were wrapped in plastic film and stored in a cooler at 2°C overnight before coring. At least six 1.27 cm diameter cores from each steak were removed parallel to the longitudinal orientation of the muscle fibres. The cores were sheared perpendicular to the muscle fibres orientation using an Instron 5543 with a Warner– Bratzler shear device and crosshead speed set at 200 mm/ min (AMSA, 1995). The considered parameter was the maximum shear force in N.

2.4. Analysis of data

In order to test the differences in consumer tenderness perception for different shear force categories, five WBs categories were built reflecting the five sensory tenderness classes. For this purpose, the regression of WBs measurements on tenderness scores was used to calculate the shear force value corresponding to the intermediate score (3) and five WBs categories were built based on the range of shear force measurements. The data were analyzed by ANOVA using the GLM procedure (SPSS, 1997). Frequency data were tested for significance using chi-square test.

Results and discussion

A total of 648 sensory ratings were collected. A preliminary analysis of the raw data of each steak by box plot showed 26 outliers responses (4.01%). According to Platter et al. (2003), these responses were removed from the data set, as outliers sensory rating responses made by individual consumers can greatly influence the average steak sensory rating; consequently the considered data were 622. Correlation coefficient of instrumental measurements with tenderness sensory ratings was -0.72 and therefore 52% of the variability of WBs was associated with variability in

sensory ratings ($P < 0.01$). The WBs value corresponding to class 3 of the sensory tenderness, calculated from the regression equation, was 47.77 N. Starting from this value, the WBs range (23.25–72.59 N) was split into 5 equidistant categories, to which the 5 classes of sensory tenderness were connected. The WBs categories were:

category 1: >62.59 N (6.38 kg);

category 2: 52.78–62.59 N (5.38–6.38 kg);

category 3: 42.87–52.68 N (4.37–5.37 kg);

category 4: 42.77–32.96 N (4.36–3.36 kg);

category 5: <32.96 N (3.36 kg).

As reported in Table 1, sensory mean scores of WBs categories 2, 3, 4 and 5, corresponding to tough, intermediate, tender and very tender meat respectively, were significantly different ($P < 0.01$). On the contrary, the mean score of category 1 was not significantly different from that of category 2. With regards to consumer tenderness perception for each WBs category, responses were distributed among the five classes of sensory tenderness in a variable way. For instance, only about 23% of the responses on meat with WBs value >62.59 N were included in the very tough meat class. The situation for meat with WBs value <32.96 kg appeared more promising, because almost 33% of the responses were included in the very tender meat class, while none were included in the very tough or tough meat classes. Considering the distribution within each sensory tenderness class, it can pointed out that no significant differences were found in class 1 between categories 1 and 2, in class 2 between category 2 and 1 and 3, in class 3 between category 3 and all the others, in class 4 between category 4 and 3. On the contrary, in class 5 category 5 differed significantly from the others. Miller et al. (1995) found that the consumer can detect a difference in WBs of about 1 kg, if meat tasting occurs in a restaurant, whereas it is about 0.5 kg if tasting occurs at home. According to Huffman et al., 1996, a change of 1 kg, or more, is necessary in order to find a noticeable difference between steaks. In our case, a difference of only 9.81 N (1 kg) between categories was probably too restrictive for the selective ability of the panel. Moreover, the consumer proved to be more inclined to classify the category 5 as very tender meat, and found it difficult to differentiate between categories 1 and 2. Hence, we decided to reduce the WBs scale to three categories, by joining the two extreme categories of the previous scale, i.e. category 2 with 1 and category 4 with 5. The results reported in Table 2 show that the mean sensory scoring of each WBs category were significantly different ($P < 0.01$). In relation to panel tenderness perception, over than 55% of consumers significantly discriminated tough from intermediate and tender meat ($P < 0.01$). Similarly, about 62% distinguished tender from intermediate and tough meat. Therefore, WBs values >52.68 N classify the meat as ‘‘tough’’ and those <42.87 as ‘‘tender’’. The following observations take into consideration the aforementioned data. The correlation coefficient of -0.72 of WBs with tenderness sensory evaluation is included in those reported by other Authors (Caine et al., 2003; Peachey, Purchas, & Duizer, 2002), who, contrary to our research, employed a trained panel. On considering the importance of the

relationship between instrumental tenderness measurement and consumer tenderness perception (Wheeler et al., 1997), our result is remarkable, especially taking into account that a consumer panel of only 220 people was employed. In our study, each cooked sample was used for both sensory evaluation and instrumental measurement and this procedure might have contributed to obtaining a higher correlation coefficient. Thus, the importance of sample preparation and evaluation setting should be emphasized. For example, Lorenzen et al. (2003) reported a lower correlation (-0.26) of WBs values with ‘‘in home’’ consumer judgements and partially attributed the lack of relationship to the variation in steak preparation encountered during ‘‘in home’’ consumer studies. Several studies have been carried out employing a trained panel in order to establish threshold values of WBs for tenderness acceptability (Boleman et al., 1997; Miller et al., 1995; Miller et al., 2001; Shackelford, Morgan, Cross, & Savell, 1991; Shackelford, Wheeler, & Koohmaraie, 1997). These values ranged from 4.31 to 5.99 kg (42.28–58.76 N). Our value of 47.77 N (4.87 kg), obtained with a consumer panel, is included between the above reported values and suggests a substantial concordance with the analytical panel. Our results indicate that beef with WBs values >52.68 N and < 42.87 N is perceived by most consumers as ‘‘tough’’ and ‘‘tender’’, respectively. Therefore, these values could represent reliable thresholds to classify beef for tenderness, with the great advantage of overcoming the practical problems of sensory evaluation.

References

AMSA (1995). Research guidelines for cookery, sensory evaluation and instrumental tenderness measurements of fresh meat. Chicago, Illinois: American Meat Science Association in cooperation with National Live Stock and Meat Board.

Boleman, S. J., Boleman, S. L., Savell, J. W., Miller, R. K., Cross, H. R., Wheeler, T. L., Koohmaraie, M., Shackelford, S. D., Miller, M. F., West, R. L., & Johnson, D. D. (1995). Consumer evaluation of beef of known tenderness levels. In Proceedings 41th international congress of meat science and technology (pp. 594–595), 20–25 August 1995, San Antonio, Texas, USA.

Boleman, S. J., Boleman, S. L., Miller, R. K., Taylor, J. F., Cross, H. R., Wheeler, T. L., et al. (1997). Journal of Animal Science, 75, 1521–1524.

Caine, W. R., Aalhus, J. L., Best, D. R., Dugan, M. E. R., & Jeremiah, L. E. (2003). Relationship of texture profile analysis and Warner–Bratzler shear force with sensory characteristics of beef rib steaks. Meat Science, 64, 333–339.

Cross, H. R., Durland, P., & Seideman, S. C. (1986). Sensory qualities of meat. In P. J. Bechtel (Ed.), Muscle as food (pp. 279–320). Orlando, Florida: Academic Press, Inc.

Culioli, J. (1995). Meat tenderness: Mechanical assessment. In A. Ouali, D. I. Demeyer, & F. J. M. Smulders (Eds.), Expression of tissueproteinases and regulation of protein degradation as related to meat quality (pp. 239–266). Utrecht: ECCEAMST.

Destefanis, G., Brugiapaglia, A., Barge, M. T., Barge, P., & Omento, E. (2004). Consumer's perception of beef tendeness. In Proceedings 50th international congress of meat science and technology, 8–13 August 2004, Helsinki, Finland.

Huffman, K. L., Miller, M. F., Hoover, L. C., Wu, C. K., Brittin, H. C., & Ramsey, C. B. (1996). Effect of beef tenderness on consumer satisfaction with steaks in the home and restaurant. Journal of Animal Science, 74, 91–97.

Koohmaraie, M. (1996). Biochemical factors regulating the toughening and tenderization precesses of meat. Meat Science, 43(Supplementary Issue), 193–201. Lawrie, R. A., & Ledward, D. A. (2006).

Lawrie's meat science. Cambridge, England: Woodhead Publishing Ltd.

Lorenzen, C. L., Miller, R. K., Taylor, J. F., Neely, T. R., Tatum, J. D., Wise, J. W., et al. (2003). Beef customer satisfaction: Trained sensory panel ratings and Warner–Bratzler shear force values. Journal of Animal Science, 81, 143–149.

Miller, M. F., Carr, M. A., Ramsey, C. B., Crockett, K. L., & Hoover, L. C. (2001). Consumer thresholds for establishing the value of beef tenderness. Journal of Animal Science, 79, 3062–3068.

Miller, M. F., Hoover, L. C., Cook, A. L., Guerra, A. L., Huffman, K. L., Tinney, K. S., et al. (1995). Consumer acceptability of beef steak tenderness in home and restaurant. Journal of Food Science, 60, 963–965.

Peachey, B. M., Purchas, R. W., & Duizer, L. M. (2002). Relationship between sensory and objective measures of meat tenderness of beef m. longissimus thoracis from bulls and steers. Meat Science, 60, 211–218.

Platter, W. J., Tatum, J. D., Belk, K. E., Chapman, P. L., Scanga, J. A., & Smith, G. C. (2003). Relationship of consumer sensory ratings, marbling score, and shear force value to consumer acceptance of beef strip loin steaks. Journal of Animal Science, 81, 2741–2750.

Risvik, E. (1995). Sensory quality of meat as evaluated by trained taste panels and consumers. In K. Lundstro}m, I. Hansson, & E. Wiklund (Eds.), Composition of meat in relation to processing nutritional and sensory quality: From farm to fork (pp. 87–93). Utrecht: ECCEAMST.

Shackelford, S. D., Morgan, J. B., Cross, H. R., & Savell, J. W. (1991). Identification of threshold levels for Warner–Bratzler shear force in beef top loin steaks. Journal of Muscle Foods, 2, 289–296.

Shackelford, S. D., Wheeler, T. L., & Koohmaraie, M. (1997). Tenderness classification of beef: 1 Evaluation of beef longissimus shear force at 1 or 2 days post mortem as a predictor of aged beef tenderness. Journal of Animal Science, 75, 2417–2422.

SPSS Inc. (1997). SPSS base for windows. Chicago, IL: SPSS Inc.

Wheeler, T. L., Shackelford, S. D., & Koohmaraie, M. (1997). Standardizing collection and interpretation of Warner–Bratzler shear force and sensory tenderness data. In Proceedings 50th annual reciprocal meat conference (pp. 68–77), Ames, IA.

Wheeler, T. L., Shackelford, S. D., Johnson, S. D., Miller, M. F., Miller, R. K., & Koohmaraie, M. (1997). A comparison of Warner–Bratzler shear force assessment within and among institutions. Journal of Animal Science, 75, 2423–2432.

Table 1 Sensory tenderness ratings distribution into five Warner-Bratzler shear (WBs) categories

WBs		Tenderness classes	*n*	WBs mean N	Sensory mean	Consumer tenderness perception				
Categories	Range N					1 Very tough %	2 Tough %	3 Intermediate %	4 Tender %	5 Very tender %
1	>62.59	Very tough	92	67.39	2.29^{A}	22.83^{Bc}	39.13^{B}	27.17^{ABab}	7.61^{Aa}	3.26^{Aa}
2	52.78–62.59	Tough	97	58.17	2.53^{A}	18.56^{Bc}	30.93^{B}	35.05^{Bb}	10.31^{Aa}	5.15^{Aab}
3	42.87–52.68	Intermediate	131	48.17	3.11^{B}	0.76^{Aa}	35.11^{B}	26.72^{ABab}	26.72^{Bb}	10.69^{ABbc}
4	42.77–32.96	Tender	201	37.67	3.42^{C}	6.47^{Ab}	12.44^{A}	29.35^{ABb}	35.82^{BCb}	15.92^{Bc}
5	<32.96	Very tender	101	28.25	4.16^{D}	–	–	16.83^{Aa}	50.50^{Cc}	32.67^{Cd}

Values within a column with different letters (a, b, A, B) differ significantly (P<0.05; P<0.01).

Table 2 Sensory ratings distribution into three Warner-Bratzler shear (WBs) categories

WBs		Tenderness classes	*n*	WBs mean N	Sensory mean	Consumer tenderness perception		
Categories	Range N					1 – Tough %	2 – Intermediate %	3 – Tender %
1	>52.68	Tough	189	62.59	2.41^{A}	55.56^{C}	31.22	13.23^{A}
2	42.87–52.68	Intermediate	131	48.17	3.11^{B}	35.88^{B}	26.72	37.40^{B}
3	<42.87	Tender	302	45.91	3.67^{C}	12.58^{A}	25.17	62.25^{C}

Values within a column with different letters (A, B) differ significantly (P<0.01).