Guaranteed Tender Beef: Opportunities and Challenges for a Differentiated Agricultural Product

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Working Paper 04-WP 371
September 2004

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Supported in part by the Agricultural Marketing Resource Center, Iowa State University.

Abstract

Participants in the beef supply chain have, at best, imperfect information about some quality attributes of the product (e.g., live animals, carcasses, or cuts) they are buying, handling, and/or processing and selling to their downstream customers. In many cases, the quality of the final product, destination, and/or appropriate handling or processing of the input is contingent on these unobservable quality attributes. Assessing the quality of an input is particularly important for firms that want to move into niche markets by differentiating their products with some attribute that consumers can only assess imperfectly prior to consumption (e.g., beef tenderness or breed). The success or failure of these ventures is often dependent on whether the selling firm is seen as dependable and trustworthy by its customers. This paper provides a summary and analysis of the literature on beef tenderness assessment and its use for classifying beef according to quality in order to cash in on the premiums consumers are willing to pay for guaranteed tender beef. Opportunities afforded by product quality differentiation are explored, and insights on the challenges of designing a classification system are provided. These challenges have led to the proposal of different thresholds by different authors. However, before any economically meaningful optimal threshold is proposed, two questions need to be clearly answered: What is the objective pursued by the system? and What are the relative consequences of rejecting a product that would have been considered tender by consumers versus certifying a product that will be considered noncompliant.

Keywords: beef tenderness, guaranteed tender beef, imperfect testing, niche marketing, product differentiation, quality uncertainty, value-added agriculture.

GUARANTEED TENDER BEEF: OPPORTUNITIES AND CHALLENGES FOR A DIFFERENTIATED AGRICULTURAL PRODUCT

Introduction

Participants in the beef supply chain have, at best, imperfect information about some quality attributes of the product (e.g., live animals, carcasses, or cuts) they are buying, handling, and/or processing and selling to their downstream customers. In many cases, the quality of the final product, the destination, and/or appropriate handling or processing of the input is contingent on these unobservable quality attributes.[1] Assessing the quality of an input is particularly important for firms that want to move into niche markets by differentiating their products with some search, experience, or credence attribute.[2,3] The success or failure of these ventures is often dependent on whether the selling firm is seen as dependable and trustworthy by their customers.

Managers at different links in the supply chain can choose to implement some sort of quality assurance system as a way to attempt to learn some relevant aspect about those attributes and provide quality certification to buyers (see Caswell, Bredahl, and Hooker 1998). Better quality assessment and certification systems are likely to be imposed if consumers value the attributes considered. Assurance can potentially come from a system run by producer alliances, from reliance on certification by a private or public third party, or both. Lawrence (2002) and Carriquiry, Babcock, and Carbone (2003) describe some systems currently used by the beef sector in Australia, New Zealand, and the United States. Important economic factors affecting the precision that decisionmakers will choose to use to assure quality in their supply chains include the market structure, the discoverability of product quality by downstream chain participants, and the nature of reputations.

Meat and animal scientists have dedicated much effort to finding objective measurements for inferring the palatability and acceptability of beef by consumers in order to certify quality on a commercial scale (or to provide cues to consumers willing to pay premiums for better beef). Given that tenderness, an experience attribute, has been shown to be the most important trait affecting beef acceptability, much of the work has been devoted to objectively measuring it and to identifying thresholds (for the measurements) that can be used to sort beef into guaranteed tender and non-certifiable beef. Identification of those thresholds, however, has proved elusive.[4] The objective of this paper is to provide a summary and analysis of the literature on beef tenderness assessment and its use for classifying beef according to quality. Opportunities afforded by product quality differentiation are explored, and insights on the challenges for designing a classification system are provided. These challenges have led to the proposal of vastly different thresholds by different authors. The main problem identified by a review of the literature is a lack of clear objectives in defining appropriate thresholds. Optimal thresholds are contingent on the objective the producer wants to achieve and/or the environment. What is best for a given objective (e.g., minimization of errors in classification) may miss the target grossly under another objective (e.g., profit maximization). The literature also makes clear that different thresholds will, under consumer heterogeneity and imperfect testing technologies, result in different magnitudes of type I (denial of certification to a tender cut) and type II (certification of a non-tender cut) statistical errors. The relative importance of each type of error must be assessed and an explicit objective stated before any economically meaningful threshold is proposed.

Guaranteed Tender Beef

Guaranteeing a good eating experience is a top priority for the meat industry in general and the beef sector in particular. In this context, segregating carcasses by tenderness is increasingly becoming an important topic, especially in the beef sector. It is worth noting that product quality and consistency can be affected (at some cost) by the beef industry. That is, the current distribution of quality offered for sale is the result of decisions made by chain participants over time.

The problem of inadequate beef tenderness is not new.[5] It has appeared within the top quality concerns identified in the National Beef Quality Audits of 1991, 1995, and 2000 (conducted by Smith et al. 1992, 1995, and 2000.[6] An experiment conducted by George et al. (1999) also illustrates the magnitude of the problem. Using a trained panel, the authors report that the approximate odds of obtaining a "slightly tough" or tougher strip loin steak at a supermarket are one in five and one in four for commodity (lower) choice and select U.S. Department of Agriculture (USDA) quality grades, respectively. These two quality grades combined account for over 80 percent of all the beef carcasses produced by fed steers and heifers (Smith et al. 1995).

In response to the identified problems the National Cattlemen's Beef Association (NCBA) created a working group of industry professionals to address this challenge (NCBA 2001). The concern of the beef industry is warranted since beef tenderness has been repeatedly reported as the most important quality attribute of meat (Huffman et al. 1996; Miller et al. 2001; Canadian Cattlemen's Association 2002). The NCBA called tenderness "the one attribute that consumers most associate with eating quality" (NCBA 2001).

Recent research has shown that consumers are able to distinguish differences in tenderness of beef loin steaks that have been classified based on Warner-Bratzler shear (WBS) force, a widely used device for measuring the tenderness of cooked meat (e.g., Miller et al. 2001; Boleman et al. 1997; Shackelford et al. 2001; Lusk et al. 2001). These studies report that consumers are willing to pay premiums for these tender steaks. For fresh meats, however, flavor and tenderness are experience attributes, and consumers have to rely on other cues to make inferences about how the product will perform (Acebrón and Dopico 2000; Dransfield, Zamora, and Bayle 1998; Steenkamp and Van Trijp 1996; Bredahl, Grunert, and Fertin 1998). Studies differ on the assessment of the accuracy of those inferences. Steenkamp and Van Trijp found a slightly significant (at a one-sided p-value of 0.1) relationship between quality expectations and quality experienced. The other two studies cited found moderate positive relations between the two. This indicates that consumers are often disappointed because their eating experience falls short of their expectations.[7]

An interesting approach aimed at improving consumer satisfaction was undertaken by Meat and Livestock Australia. This producer-owned company has developed a grading system called Meat Standards Australia (MSA), with the focus of providing consumers a guaranteed satisfactory eating experience. In contrast to assessment of carcass traits at the chiller, MSA has taken a total system approach to grading meat, based on the principles of Palatability Assurance at Critical Control Points, a concept borrowed from the food safety sector (Polkinghorne et al. 1999). The aim is to control the critical points that impact meat quality, from production to processing and through the value-adding links of the beef chain. Briefly, Meat and Livestock Australia has conducted large-scale, carefully planned experiments using consumer taste panels, with a focus on factors identified in the literature as affecting beef palatability. Consumers were asked to rate samples of beef for tenderness, juiciness, flavor, and overall satisfaction. These ratings were used to construct an index of quality, with the highest weight (40 percent) placed on tenderness. Consumers were also asked to classify the sample as either “unsatisfactory” (no grade), “good everyday” (3 star), “better than everyday” (4 star), or “premium quality” (5 star). The quality index was then used to calculate optimal boundaries for the grades assessed by consumers using linear discriminant analysis. The boundary between unsatisfactory and 3 star (representing the pass/fail criteria) was then adjusted up for further protection.

The MSA example indicates that participants in the beef supply chain can transform the experience attribute “tenderness” into a search attribute (see endnote 2) by testing, sorting, and carefully labeling.[8] This creates an opportunity for alliances among producers who wish to develop a niche marketing venture. It seems that there are premiums (see section on benefits and costs) that can be fetched by “guaranteed tender” beef.[9] Some producer groups and food corporations have already tapped into this market. One of the enterprises, Beefmaster Cattlemen LP (located in Texas), has been allowed by the USDA to label its products as “all natural tender aged beef,” and it commands significant premiums for its products. The procedure used by this venture to assure tenderness is selection of USDA Select carcasses, with yield grades lower than 3, having a certain weight and ribeye area, and being devoid of visible defects. Selection of carcasses is accomplished with the BeefCam technology (more on this technology later). Eligible carcasses are electrically stimulated and aged at least 14 days before they are shipped to retail warehouses.

However, the technology used to identify and certify guaranteed tender must be accurate enough to result in beef products that are recognized by consumers as superior in tenderness (Ward et al. 2004). Most often, beef products are sorted for tenderness by type of cut and USDA quality grades (NCBA 2002).[10] Although USDA quality grades are correlated with consumers’ ratings of beef palatability, using this classification criterion will fail to convey precise information to consumers about the tenderness of the product

(Savell et al. 1987). USDA quality grades have been recognized as not differentiating appropriately the tenderness of steaks taken from the longissimus muscle of USDA Select or Low Choice fed-beef carcasses (Wulf et al. 1997).[11] Further, Shackelford et al. (2001) argued that consumers can detect differences in tenderness within Select strip loins after 14 days of postmortem aging. This is significant, since Choice and Select account for over 90 percent of the graded carcasses (Boleman et al. 1998). More broadly, Wheeler Cundiff, and Koch (1994) found that marbling explained at most just 5 percent of the variation in beef palatability. Comparing the USDA grading system with MSA and the Japanese Meat Grading Association System, Strong (2001) concluded that the wide variation of eating quality within each USDA quality grade is not surprising, since the system does not consider many factors proven to affect quality.

It is well established that to increase the probability of obtaining satisfactory tenderness, the best genetics should be used, and appropriate management practices should be followed during growth, slaughter, and processing of carcasses. However, Koohmaraie et al. (1996) cautioned that the relation between breed and tenderness is not strong, since variation of tenderness *within* breeds is larger than variation across breeds.[12] Hence, as Schroeder et al. (1998, p. 10) concluded, "…producer alliances with the goal of targeting beef to specific markets demanding particular quality attributes will likely find success elusive if they rely predominantly on current beef quality grades, cattle breeds, and genetics to ensure tenderness and consistency of their products. Producers may also need to employ some type of tenderness testing." This claim is significant, since only one of the 40 certified beef programs registered with the USDA rely on such measurements.[13] Broadly speaking, all these programs require is some distinctive genotypic and/or phenotypic characteristics combined with eligible USDA quality and yield grades (with variable stringency) and the absence of visible defects such as hemorrhages or dark cuts.[14] All these requirements are conducive to more tender meat, but there are still significant amounts of unexplained variation in consumers' perceptions. Scientists have concluded that "the beef industry must identify more precise methods [than USDA quality grades] of distinguishing palatable from unpalatable beef" (Wulf and Page 2000, p. 2595), and, along the same line, "a direct measure of meat tenderness is needed to supplement quality grade" (Wheeler, Cundiff, and Koch 1994, p. 3150).

Prediction of Tenderness

For commercial utilization, real-time measurements are needed to classify carcasses according to tenderness. Despite tremendous efforts by animal and meat scientists, accurate prediction of consumer perceptions of beef tenderness has proved elusive. Further, Lorenzen et al. (2003) concluded that predicting consumers' ratings of beef based on laboratory procedures (trained panels, WBS force) is inherently difficult, because cooking method, degree of doneness, seasoning, and individual heterogeneity in preferences all affect the way consumers perceive the quality of the product. Shackelford, Wheeler, and Koohmaraie (1997, p. 2421) argued that the ideal method for measuring or predicting meat tenderness would be through "an accurate, rapid, automated, tamper-proof, noninvasive machine." Several technologies have been investigated for the purpose of replacing the time-consuming and destructive measurement of WBS force. Some examples include near-infrared reflectance spectra (Park et al. 2001); image texture analysis (Li, Tan, and Shatadal 2001); neural network modeling (Hill et al. 2000); measurements of muscle color, pH, and electrical impedance (Wulf and Page 2000); and BeefCam (Vote et al. 2003). Wheeler et al. (2002) showed that slice shear force was more accurate (than the latter two) at identifying beef cuts that can be guaranteed tender. Further, the authors concluded that commercial BeefCam provided added assurance of acceptable tenderness over USDA quality grade, but refinements seem necessary to enhance the ability of BeefCam to identify carcasses that will yield acceptably tender meat. In another work, Wyle et al. (2003) reached a similar conclusion that BeefCam might ultimately be useful in identifying carcasses for inclusion in branded beef programs, but further development and testing of the technology is warranted.

In view of the difficulty in predicting consumers' ratings accurately, researchers often try to segregate carcasses into classes (e.g., either tender or tough) according to some criteria. The most commonly used procedure is to classify carcasses according to the WBS or slice shear force, measured in the longissimus.[15] Since sufficiently accurate and less invasive (costly) methods are not available (yet), effort is being placed on determining thresholds for WBS or slice shear force values to be used in the classification process. In particular, this is one of the objectives of the Instrumentation Working Group of the National Beef Instrument Assessment Plan II (NCBA 2002). The first thresholds for

WBS force were proposed by Shackelford et al. (1991). They suggested threshold values of 4.6 kg and 3.9 kg as approximate cutoffs for obtaining 50 percent (corresponding to the mean) and 68 percent (mean minus standard deviation)[16] chances of a steak being rated slightly tender or better, respectively, recognizing that the confidence of having more stringent standards may be offset by higher production costs because of lower acceptance rates. Though not mentioned in the study, the trade-offs between type I and type II statistical errors are nicely illustrated. For example, 6.6 percent and 16.9 percent of the predicted tough cuts were actually tender (rated at or higher than slightly tender by a trained panel) for the 50 percent and 68 percent confidence limits, respectively. On the other hand when comparing the 50 percent and 68 percent confidence limits, the percentage of cuts predicted tender that were actually tough (rated lower than slightly tender) decreased from 6.7 percent to 1.6 percent. Another example can be found in Wheeler, Shackelford, and Koohmariae 1997. These authors adapted the data from Huffman et al. (1996) to show that steaks rated as acceptable had WBS forces as high as 5.7 kg, whereas values as low as 3 kg were rated unacceptable, indicating a significant overlap. Both types of error will arise for the proposed threshold of 4.1 kg, which led to 98 percent consumer overall satisfaction with the steaks.

The problem just discussed is not to be seen as exclusive to the prediction of tenderness. Thompson et al. (1999) argue that the MSA system worked well in the sense that it reduced the probability that a consumer will receive an unsatisfactory steak (11 percent for striploins). However, there were a significant proportion of carcasses (71 percent) that failed to meet the 3-star specifications but were deemed acceptable by consumers. The developers of MSA recognize this as a problem with the methods or pathways used to determine acceptability but argue that a “minimal risk approach was necessary in the interests of guaranteeing consumer satisfaction” (Thompson et al. 1999, p. 2).

The number of tenderness classes[17] needed to maximize carcass value and consumer satisfaction is an unsettled question and an area for future research (Wheeler, Shackelford, and Koohmaraie 1997; Shackelford, Wheeler, and Koohmaraie 1999). It is also unclear where the lines separating the tenderness classes should be drawn. Carriquiry (2004) focuses on where to draw the line for two classes. Previous research identified the best system for classifying carcasses as the one that matches most closely the perceptions of either trained panels or consumers. Arbitrary values of WBS force (e.g., 5 kg in Shackelford, Wheeler, and Koohmaraie 1999) at 14 days of aging were used as benchmarks. However, none of the studies provides an economic assessment of the implications of different benchmarks. For example, setting the standards higher may confirm the prediction more frequently, but it will also lead to a large number of false rejections (or statistical type I error). Setting the standards lower will likely lead to fewer false rejections, but a higher proportion of the certified tender beef will be perceived by consumers as not complying (type II statistical error). The correct standard from an economic standpoint must balance these two types of errors with the potential premiums and costs of segregation by tenderness in an economically meaningful fashion.

Testing and/or classifying a product (even with nondestructive methods) entail costs. Producers will be willing to implement a certification system if they perceive there are price premiums that can be fetched through better sorting. Hence, before any effort is incurred in designing a sorting and certification system, one question should be answered: Are there premiums that can be fetched by guaranteed tender steaks? More importantly, are those premiums higher than the costs of implementing the certification system?

Benefits and Costs of a Tenderness-Certified Program

Any tenderness certification system will add costs. These costs can be broadly classified into two categories: tenderness assessment (or testing) and sorting costs. Wheeler, Shackelford, and Koohmaraie (1999) "crudely estimated" the cost of classification using an automated system using slice shear force to measure tenderness (once developed) at $4.35 per carcass. They estimated the costs of manual classification at $8.50 per carcass. Included in those cost estimates are labor (at $25/hr), equipment, and the sample that needs to be destroyed for testing (a one-inch ribeye steak valued at $4). However, as Lusk et al. (1999) observed, actual costs will likely be larger since the previous estimate ignores additional sorting costs and the cost of capital financing. One could also add the costs associated with errors in the certification process. Other available technologies, such as BeefCam, may result in lower costs.

Consumer willingness to pay premiums for tender beef has been documented by recent studies. Lusk et al. (2001) reported average premiums of $1.84 per pound for guaranteed tender steaks and 20 percent of consumers were willing to pay a premium of $2.67 per pound or more. In another study conducted by Shackelford et al. (2001), half of the consumers indicated that they would definitely or probably be willing to pay 50¢ more per pound for the guaranteed tender Select steak.[18] Boleman et al. (1997) reported that most of the families who purchased steaks in an experiment (94.6 percent) chose steaks revealed to be tender over both intermediate and tough steaks (segregated by shear force), even though a $1.10/kg difference was placed between each category. In a somewhat surprising response, half of the consumers (surveyed by Shackelford et al. [2001] in Denver, Colorado) indicated they do not let price govern their food-purchasing decisions.[19]

Benefits or premiums accrue only on carcasses that are certified as tender, whereas costs are incurred for all the carcasses tested. In an error-free world, where cuts can be perfectly classified (based on the result of the measurements) into acceptable and unacceptable, the profitability of a certification system depends only on the price premiums for high quality, costs of testing and sorting, and the fraction of the tested population that can be certified (assuming that packers cannot strategically misrepresent the results of the tests[20]). Ward et al. (2004) argued that the proportion of qualifying carcasses plays a key role in determining whether a system to guarantee tenderness is feasible. Letting λ be the fraction of tested carcasses that can be sold in the high quality market, p be the price premium for that quality, and C be the incurred costs per tested carcass, a system will be implemented whenever, $\lambda p - C \geq 0$. Rearranging the inequality as $p \geq C/\lambda$ makes clear that a classification system will be feasible only if the price premiums exceed the costs per certified carcass. The inequality could also be rearranged as $\lambda \geq C/p$; the larger are the costs of certification relative to the premiums, the higher is the fraction of high-quality carcasses needed for the system to be profitable.[21] In the real world, the issue is not that simple. Packers face uncertainty about both the real quality of the carcasses (even after grading and/or performing tests) and about differences among consumers. A steak that is perceived as tender by a consumer in a given circumstance may not be rated the same by another buyer or in another situation. Additionally, the proportion of carcasses that is certified is under the control of the alliances, whose objectives may conflict with minimization of the number of classification errors.

Providing Information to Customers: Is Certification Important?

Perception of foods in general, and meats in particular, depend both on their intrinsic properties and on how they interact with external factors, such as price, information, and previous experience (Dransfield, Zamora, and Bayle 1998). It is generally accepted that consumers' expectations about product quality are based on perceptions of one or more quality cues. Steenkamp and Van Trijp referred to quality cues as any "informational stimuli that can be ascertained through the senses prior to consumption, and, according to the consumer, have predictive validity for the product's quality performance upon consumption" (1996, p. 197). Quality cues can be divided into intrinsic and extrinsic. The former refer to attributes that are part of the physical product and cannot be changed without altering the product itself (e.g., color and marbling for beef). Extrinsic quality cues (e.g., price and brands) are not part of the product but rather the result of marketing efforts.

Providing consumers with information has a potentially significant impact on quality perception and preferences (Dransfield, Zamora, and Bayle 1998). For example, samples of beef labeled "75 percent lean" received better quality ratings than identical samples labeled "25 percent fat" (Levin and Gaeth 1988). Shackelford et al. (2001) indicated that 80 percent of consumers believed that steaks carrying a label "Tender Select" (and a statement guaranteeing tenderness) were tenderer than other fresh beef cuts. Explicit information (in terms of guaranteed tenderness) significantly altered consumers' perceptions and revealed preferences about steaks in a study conducted by Lusk et al. (2001). In that study, consumers were asked to test two samples coming from steaks that differed widely in terms of tenderness (measured by slice shear force[22]). Information about the differences in tenderness of the steaks increased the percentage of consumers preferring the tender steak from 69.16 to 83.72 percent and the percentage of consumers willing to pay a premium from 36.12 to 51.16 percent. In another study, Boleman et al. (1997) found that informing people about the tenderness classification increased the proportion of steaks purchased by families (after tasting) from the tenderest category from 55.3 to 94.6 percent. The current discussion suggests that certifying tenderness provides credit to producers, in the sense that consumers' acceptability (or perceptions) of products after consumption is positively affected by expected quality.

A study conducted by Dransfield, Zamora, and Bayle (1998) indicated that for some consumers quality is more important than price in determining purchasing decisions. According to the authors, there is a wide range of qualities in the market that do not command price differences because the eating experience is not known to the consumer prior to purchase. A careful sorting of carcasses and appropriate labeling could in principle be used by beef alliances to cash in on consumers' willingness to pay for high-quality products, in particular for "guaranteed tender beef."

Conclusions

This paper reviews the literature on beef tenderness assessment and its potential use by groups of producers to cash in on the premium consumers are willing to pay for guaranteed tender beef. Potential challenges to classification of beef according to tenderness were also identified, pointing to the difficulties generated by errors resulting from the imperfect tenderness measurement technologies currently available and by consumer heterogeneity.

Different authors have proposed widely different thresholds. This is believed to be the result of the difficulties previously mentioned combined with the lack of clearly defined objectives. Before any economically meaningful optimal threshold is proposed, two questions need to be clearly answered: What is the objective pursued by the system? and What are the relative consequences of rejecting a product that would have been considered tender by consumers versus certifying a product that will be considered noncompliant?

More information is needed before any meaningful discussion about the optimal number of tenderness classes is conducted. For that purpose, it is clear that research is needed to learn more about consumers' abilities, preferences, and willingness to detect and pay for increasingly subtler differences that would result as the grid of quality is more finely divided. To obtain useful answers, these studies should elicit from consumers their perceptions of what tenderness levels are not only acceptable but also acceptable for a guaranteed tender premium beef market.

Endnotes

1. For example, tough cuts have very different potential markets, uses, or require different preparation than their opposites.

2. The terms "search" and "experience" were introduced by Nelson (1970). The term "credence attributes" was coined by Darby and Karni (1973). For search and experience attributes, consumers can gain information about product quality before or after consumption, respectively. Quality can not be learned by consumers (even after consumption) for credence attributes.

3. A partial list of meat attributes falling in these categories is organic, natural, tender beef, and free range. For a list of existing alliances in the beef sector and a rationale for that form of organization, see Schroeder and Kovanda 2003.

4. The most commonly used measure in experiments are Warner-Bratzler and slice shear force, the force needed to shear cooked beef (see, for example, Shackelford et al. 1991; Huffman et al. 1996; Miller et al. 2001).

5. Morgan (1995) reported losses of $216,976,000 for tenderness-related problems.

6. Morgan et al. (1991) also reported that beef tenderness variability was of primary concern to the U.S. industry.

7. Lockhart (2000) quoted Brad Morgan, assistant professor of animal science at Oklahoma State University, as saying, "one out of five beef eating experiences will be less than desirable."

8. The issues in transforming credence and experience attributes into search attributes in food products are discussed by Caswell and Mojduszka (1996).

9. For the industry as a whole, classifying cuts by tenderness is a more delicate issue. If classification becomes the norm, there will be a reduction in value for all the non-qualifying (probably tough) cuts, and the overall balance is not clear. This is a concern for the beef industry (Schroeder et al. 1998; Ward et al. 2004), but the NCBA's efforts to develop better (tenderness) sorting technologies seem to indicate that the industry perceives the benefits of doing so.

10. These grades are based on the relationship between marbling of the twelfth rib cross section of the longissimus and cooked beef palatability (USDA 1997).

11. Miller et al. (2001) were able to produce (strip loin) steaks within the Select grade that were rated from extremely tough to extremely tender by a panel of consumers by varying the aging period of the different steaks. The animals were all steers of the Simbrah breed, fed in the same feedlot, subject to similar implant and feeding strategies. Before being slaughtered at a commercial processing facility, all animals were fed for 180 to 210 days. The steaks were cooked by trained research teams to the same degree of doneness, at the same time, and on the same day to avoid other sources of variability.

12. Hilton et al. (2004) found no differences in WBS force and sensory panel tenderness ratings among six different phenotypes (all including less than one-fourth Brahman). The authors then concluded that any cattle phenotypes with one-fourth or less phenotypic expression of Brahman can be used in a guaranteed tender program.

13. The only program that attempts to measure tenderness is Nolan Ryan Tender-Aged Beef. However, research conducted by Gheno et al. (2001) concluded that the resulting tenderness in this program as measured by WBS force or trained panel evaluations is no better than that of USDA Choice.

14. The most salient of these alliances, Certified Angus Beef, accounted for 5.7 percent of all the fed cattle slaughtered in 2001 (Schroeder and Kovanda 2003).

15. Of course, this only predicts the tenderness of this muscle. The correlation between shear force of the longissimus and other muscles is generally low (Shackelford, Wheeler, and Koohmaraie 1995).

16. To conduct the analysis, the authors assumed shear force in the population of cattle to be normally distributed.

17. More information regarding the consumer ability and willingness to distinguish and pay for subtler tenderness differences is required to address this issue meaningfully. This would also require more precise technologies to assess tenderness.

18. This study does not give us a good sense of consumers' willingness to pay for tender steak, since it only asked, "How willing would you be to pay 50¢ per pound…more to purchase that steak?" Hence, the only information we can extract is that half of the consumers are willing to pay at least a 50¢ per pound premium for the guaranteed tender Select steak.

19. The sample used was not representative of the general population, since 58.1 percent of the respondent households reported incomes above $60,000. However, this could be a good sample for research of acceptance of value-added products.

20. This could be the case, for example, when packers reveal the result of the measurements, and consumers buy only those cuts they know will meet their expectations. In reality, consumers will not be able to perfectly "self-select," because of a lack of perfect links between quality measurements and actual perceptions.

21. Suppose that only the rib and loins area can be certified (usually the area tested; more on this to follow). According to Miller et al. (2001), those cuts would represent 137 lbs. of sealable steaks per carcass. For the manual system costs reported by Wheeler, Shackelford, and Koohmaraie (1999) and the conservative premiums (lower bound) reported by Shackelford et al. (2001), a proportion $\gamma \geq (\$8.5/137\text{ lbs})/\$0.5 = .12$ is enough to warrant the implementation of a certified tender system, in an error-free world.

22. In this study, the information was provided in terms of the very suggestive names of "guaranteed tender" and "probably tough" (after an objective measurement of tenderness). "Guaranteed tender" steaks had a slice shear force lower than 15 kg, whereas "probably tough" steaks had a slice shear force higher than 35 kg.

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