

# Pre-Harvest Cattle Management Practices for Enhancing Beef Tenderness

## EXECUTIVE SUMMARY

*Prepared for the National Cattlemen's Beef Association*



# Pre-Harvest Cattle Management Practices for Enhancing Beef Tenderness



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**March 2006**



*“The end-product is taste...  
People will pay more for greater satisfaction, and  
taste is their measure of satisfaction in food...  
Meat producers who are customer-driven must  
seek to influence the factors that affect taste all  
the way from the field to the table.”*

*(Feargal Quinn, 1999)<sup>1</sup>*



MANAGEMENT  
OF  
BEEF TENDERNESS  
IN  
COORDINATED  
BEEF  
SYSTEMS



Pre-harvest management of beef tenderness has become an important topic in today's cattle industry due to the fact that tenderness is the primary determinant of eating satisfaction among beef consumers<sup>2</sup> and because structural changes in the beef industry<sup>3</sup> have resulted in greater vertical coordination of production, processing, and marketing activities, making it feasible to manage product attributes along the entire beef chain. Over the past several years, beef producers have worked diligently to identify primary drivers of consumer demand and to become more responsive to consumer needs by improving the quality, safety and

convenience of their products. Cattle producers who operate successfully in today's vertically coordinated business structures possess a heightened awareness of consumers' preferences and embrace production goals that are more clearly focused on satisfying the end-users of their products. As Boehlje (1995) observed:

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*"The produce-and-then-sell mentality of the commodity business is being replaced by the strategy of first asking consumers what they want as attributes in their food products and then creating or manufacturing those attributes in the products."*<sup>4</sup>

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The basic tenet of Total Quality Management (TQM) is to improve the production system in order to prevent product defects, rather than inspecting finished products and, then, removing those that do not conform to quality specifications.

“Tenderness management systems” (based on application of TQM principles) involve control and verification of specific processes in the production chain that impact tenderness, and may be utilized to differentiate beef products on the basis of palatability performance, with the ultimate goal of adding value to cattle. A growing body of scientific evidence suggests that several different pre-harvest factors (both genetic and non-genetic) influence the eating qualities of beef and can be managed systematically to enhance quality characteristics of the end product.<sup>5</sup> Key elements of effective pre-harvest beef tenderness management systems (i.e., process control points) include:

- control of breed/genetic inputs,
- use of feeding systems that enhance product quality,
- judicious application of growth enhancement technologies, and
- adherence to best management practices to avoid quality and tenderness problems associated with the effects of morbidity, pre-harvest stress, administration of animal health products, and hormonal status of the animal.



## MANAGING GENETIC INPUTS



Optimizing cowherd productivity across the broad range of beef production environments in the U.S. requires the use of diverse biological types of cattle that differ with respect to size, milk production, growth and maturing rates, and adaptability to regional differences in feed resources and climatic conditions. The

high degree of genetic diversity among and within the various breeds and biological types of cattle currently utilized in U.S. beef production systems, while advantageous from a production standpoint, represents an important source of variation in beef tenderness. Correspondingly, the selective use of breeds and selection of



**TABLE 1.**

Comparison of carcass quality and beef tenderness characteristics for eight of the most widely used cattle breeds in U.S. production systems

Breed	Type	Age-constant means <sup>a</sup>		
		Marbling score	% Choice & higher	Shear force, kg
Angus	<i>Bos taurus</i> /British	SM <sup>88</sup>	88	4.0
Hereford	<i>Bos taurus</i> /British	SM <sup>26</sup>	65	4.1
Red Angus	<i>Bos taurus</i> /British	SM <sup>90</sup>	90	4.1
Charolais	<i>Bos taurus</i> /Continental	SM <sup>17</sup>	62	4.3
Gelbvieh	<i>Bos taurus</i> /Continental	SM <sup>06</sup>	58	4.5
Limousin	<i>Bos taurus</i> /Continental	SM <sup>04</sup>	57	4.3
Simmental	<i>Bos taurus</i> /Continental	SM <sup>27</sup>	66	4.3
Brahman	<i>Bos indicus</i> /Zebu	SL <sup>73</sup>	30	5.9

<sup>a</sup>Source: Wheeler et al., 2001, 2005. SM = Small, SL = Slight. Lower shear force values are indicative of greater tenderness

specific genetic lines within breeds, both warrant consideration as pre-harvest process control points for managing beef tenderness.

### *Balancing Strengths of Diverse Breeds.*

Carcass quality and beef tenderness characteristics of eight of the most widely utilized beef cattle breeds in today's U.S. production systems are compared in Table 1.<sup>6,7</sup> The three British breeds (Angus, Hereford, and Red Angus) listed in Table 1 represent the most frequently utilized maternal-type breeds in U.S. commercial beef herds and have a long-standing reputation for producing high-quality, tender beef. Data in Table 1 suggest that all three British breeds produce beef with superior tenderness, while the Angus and Red Angus breeds excel in both tenderness and carcass quality grade performance. The four most prevalent Continental breeds (Charolais, Gelbvieh, Limousin, and Simmental) are used extensively in crossbreeding systems, not only for their positive contributions to growth performance and red meat yield, but also,

in some cases, to enhance maternal performance. Beef produced by the Continental breeds is very acceptable in tenderness, but ranks slightly lower with respect to average tenderness (i.e., slightly higher shear force) than beef from British breeds of cattle (Table 1).

While all of the *Bos taurus* breeds listed in Table 1 (and several others not listed here) merit consideration for use in consumer-driven breeding systems, producers whose goals are focused specifically on production of high-quality, tender beef should emphasize use of breeds with lower mean shear force values and higher mean marbling scores.

Crossbreeding systems that result in feeder cattle with 50 to 75% British and 25% to 50% Continental breed influence are recommended for balancing the growth performance and carcass yield advantages of the Continental breeds with the maternal performance and beef quality advantages of the British breeds.<sup>8</sup>

Increasing numbers of commercial cattlemen are using hybrids (e.g., Balancer, LimFlex, SimAngus, etc.) or composites in their breeding

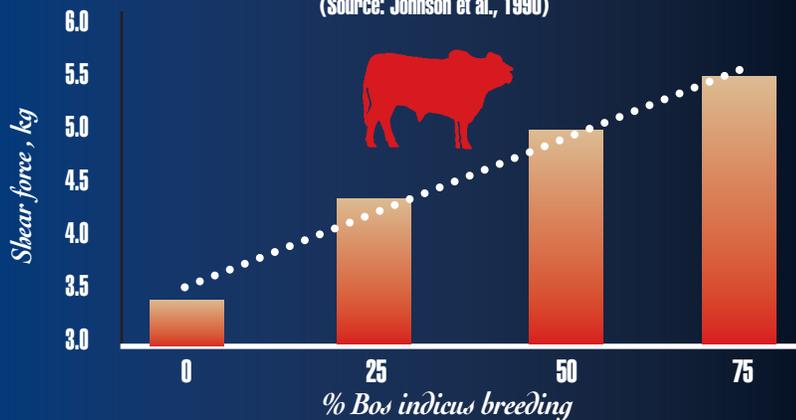
programs to attain the desired mix of British and Continental breeding, while capitalizing on performance advantages stemming from heterosis and breed complementarity.

The Brahman breed (a *Bos indicus* or Zebu breed) is the most widely utilized tropically adapted cattle breed in the U.S., and offers distinct production advantages for cattle producers in the southern region of the country. Among the various cattle breeds commonly used in U.S. production systems, the most pronounced between-breed tenderness differences exist between *Bos indicus* and *Bos taurus* breeds (Table 1). Cattle of the various *Bos indicus* breeds consistently have been shown to produce beef that is less tender than beef from *Bos taurus* breeds of cattle.<sup>6,9,10</sup> Correspondingly, tenderness tends to decrease (i.e., shear force increases) almost linearly (see Figure 1) as percentage of *Bos indicus* breeding increases.<sup>11,12</sup>

An effective strategy for enhancing tenderness via the selective use of breeds is to moderate the percentage of *Bos indicus* breeding in market steers and heifers.

**Figure 1.**  
**Percentage of *Bos indicus* breeding and longissimus shear force**

(Source: Johnson et al., 1990)



Research suggests that limiting *Bos indicus* inheritance to 3/8 (37.5%) or less is effective for reducing the incidence of tenderness problems.<sup>13, 14</sup> For producers who operate in subtropical or tropical environments, substituting a tropically adapted non-Zebu breed (e.g., Romosinuano, Senepol, Tuli) for the *Bos indicus* breed component in the development of heat-tolerant composites also may be a viable strategy for managing tenderness.<sup>15</sup> When it is not possible to document actual percentages of *Bos indicus* inheritance among groups of cattle, live animal and (or) carcass specifications based on phenotype can assist in the assurance of acceptable tenderness.<sup>16</sup> For example, several branded beef programs currently

include carcass specifications that utilize hump height as a phenotypic indicator of *Bos indicus* breeding.

#### *Within-Breed Selection to Improve Tenderness.*

Heritability estimates from a number of studies suggest that tenderness is moderately heritable ( $h^2 = 0.24$  to  $0.53$ ) in *Bos taurus* and *Bos taurus* x *Bos indicus* cattle populations,<sup>6, 10, 15, 17-19</sup> but lowly heritable ( $h^2 = 0.14$  to  $0.17$ ) in pure strains of Brahman cattle.<sup>20, 21</sup> Seedstock and commercial cattle breeders have relied on traditional methods, such as progeny testing, to obtain beef tenderness information for selection purposes. Consequently, the time and expense required to change tenderness via traditional selection methods have been

major impediments to genetic improvement of beef tenderness.

For beef programs that involve collection of tenderness data for sire-identified progeny groups, preferential use of specific sires whose progeny produce beef with superior tenderness (i.e., selection of “tender” sires) is fundamentally effective for enhancing tenderness.<sup>5</sup> To facilitate selection of sires for long-term genetic improvement in tenderness, several breeds are developing and reporting Expected Progeny Differences (EPD) for tenderness.<sup>22</sup> In addition, there is a growing number of commercially available DNA markers for genes associated with differences in beef tenderness and some breeders have begun DNA testing of seedstock, awaiting further validation and evaluation of the usefulness of marker-assisted selection for improving beef tenderness. Gene markers that prove effective for identifying genetic differences in tenderness among breeding cattle offer tremendous potential for augmenting traditional methods of selection for improved beef tenderness.<sup>23</sup>

**Grain Feeding.** Cattle feeding systems in the U.S. are designed specifically to produce grain-fed beef, which is demanded by most mainstream markets (both domestic and export). Studies comparing quality characteristics of forage-fed and grain-fed beef have demonstrated that grain feeding improves several carcass indicators of beef quality. Grain-fed cattle produce carcasses with brighter-colored, finer-textured lean,<sup>24</sup> whiter fat,<sup>25</sup> and more marbling,<sup>26</sup> all of which enhance acceptability of fresh retail beef.<sup>27</sup> In addition, most comparisons of forage-fed and grain-fed beef suggest that grain feeding improves tenderness and flavor.<sup>28</sup> For producers interested in labeling and merchandising beef products as “Grain Fed,” the USDA has defined a grain diet as “any cereal plant product that meets or exceeds 60 Mega calories Net Energy for gain (NE<sub>g</sub>) per 100 pounds dry matter” and has specified that, for cattle to meet USDA process verification standards for “Grain Fed,” average grain consumption must equal 50% or more of the ration, with a minimum of 100 days on feed.<sup>29</sup>

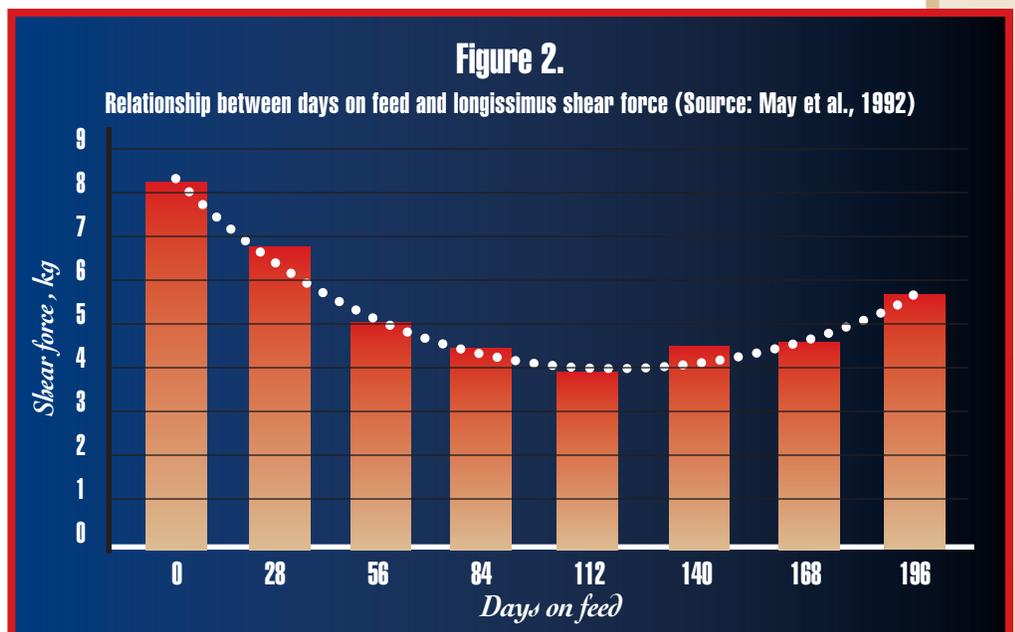
**Days On Feed.** Though only a small number of cattle targeted for U.S. beef markets are forage-finished, a great number of

young, stocker cattle are backgrounded (grown) on various forages (grazed or harvested) for several months before receiving high-concentrate, finishing diets.<sup>30</sup> Cattle that are grown on relatively low-energy, forage diets must be fed a high-concentrate diet for a sufficient period of time in order to develop the carcass quality characteristics and beef palatability attributes normally associated with those of grain-fed beef. Research conducted to characterize the relationship between time-on-feed (the number of days cattle are fed a high-concentrate finishing diet) and beef palatability attributes has shown that most improvements in both tenderness and flavor occur during the early portion of the finishing period (before 112 days on feed),<sup>31-34</sup> and that finishing periods

## FEEDING SYSTEMS



longer than approximately 100 days seem to provide little additional improvement in either tenderness (see Figure 2) or flavor.<sup>31-37</sup> Feeding yearling cattle a high-concentrate, finishing diet for periods longer than 180 days has been shown to be detrimental to tenderness due to increased maturity.<sup>38</sup> Correspondingly, to minimize the incidence of toughness problems stemming from advanced maturity, grain-finished cattle should be harvested at young ages – preferably less than 24 months of age.<sup>39</sup>



## USE OF GROWTH ENHANCEMENT TECHNOLOGIES



Conventional beef production systems in the U.S. involve the use of anabolic implants during one or more phases of production prior to harvest. Implants, administered to growing and finishing cattle, significantly increase net returns by increasing both rate and efficiency of weight gain, primarily by enhancing protein accretion. Implanting improves daily gain by approximately 6% in suckling calves,<sup>40</sup> 12 to 16% in stocker cattle,<sup>41</sup> and 15 to 25% in feedlot cattle.<sup>42</sup> Moreover, implanting cattle during the pre-weaning and stocker phases of production has been shown to have little impact on subsequent growth performance during finishing.<sup>41, 43</sup> Duckett and Andrae (2001) estimated that the cumulative effects of implants used in each successive phase of production (suckling, stocker, and feedlot) would increase live weight by approximately 125 pounds and add more than \$90 to the value of each animal.<sup>44</sup> Because the effects of implanting are so effective for enhancing profitability in all stages of production, very few cattle

reach market weight without having received at least one implant at some point in the production chain, and many cattle receive multiple lifetime implants as they proceed through various stages of production.<sup>45</sup> The obvious exception would be cattle that are produced for one of the growing number of natural beef programs.

### *Pre-Finishing Implants.*

Only a few studies have investigated the effects of pre-finishing implants on product tenderness. Existing evidence, though limited, suggests that the low-potency implants commonly used in suckling calves and stocker cattle do not adversely affect beef tenderness;<sup>46, 47</sup> however, repetitive use of estrogenic implants has been shown to increase carcass maturity<sup>46-49</sup> and use of multiple lifetime implants may reduce marbling scores.<sup>48</sup> Correspondingly, Platter et al. (2003) advocated limited use of pre-finishing implants in coordinated beef systems to minimize the risk of detrimental effects on beef quality.<sup>47</sup>

### *Finishing Implants.*

Results of a USDA survey of the U.S. feedlot industry<sup>50</sup> suggest that over 97% of all feedlot cattle receive one or more implants during finishing. The number of implants administered to feedlot cattle depends upon the projected duration of the finishing period. Heavyweight feeder

cattle (> 750 pounds for steers and > 700 pounds for heifers) fed fewer than 130 days typically receive only one finishing implant. Lighter-weight cattle requiring finishing periods of 130 days or longer usually receive two sequential finishing implants, with the terminal implant administered 70 to 120 days before harvest.

Very lightweight calves (< 450 pounds), projected to require 230 or more days of finishing, sometimes receive three implants during finishing.<sup>51</sup> However, based on industry survey results, only about 6% of the cattle entering U.S. feedlots weighing less than 700 pounds would receive more than two implants.<sup>50</sup>



**Table 2.**  
**Commonly used cattle finishing implants<sup>a</sup>**

Trade name	Approved use	Estrogen, mg	Androgen, mg	Estimated effectiveness, d
<i>Estrogenic (E):</i>				
Component E-S	S	14 E <sub>2</sub>		120
Synovex-S	S	14 E <sub>2</sub>		120
Compudose	S/H	25.7 E <sub>2</sub>		175
Duralease	S/H	14 E <sub>2</sub>		175
Encore	S/H	43.9 E <sub>2</sub>		350
Ralgro Magnum	S	72 Zeranol (22-26 E <sub>2</sub> activity)		90
Ralgro	S/H	36 Zeranol (11-13 E <sub>2</sub> activity)		70
<i>Androgenic (A):</i>				
Component T-S	S		140 TBA	105
Component T-H	H		200 TBA	105
Finaplix-H	H		200 TBA	105
<i>Combination (E+A):</i>				
Component TE-IS	S	16 E <sub>2</sub>	80 TBA	110
Revalor-IS	S	16 E <sub>2</sub>	80 TBA	110
Synovex Choice	S	10 E <sub>2</sub>	100 TBA	120
Component TE-S	S	24 E <sub>2</sub>	120 TBA	120
Revalor-S	S	24 E <sub>2</sub>	120 TBA	120
Component TE-IH	H	8 E <sub>2</sub>	80 TBA	110
Revalor-IH	H	8 E <sub>2</sub>	80 TBA	110
Component TE-H	H	14 E <sub>2</sub>	140 TBA	120
Revalor-H	H	14 E <sub>2</sub>	140 TBA	120
Component E-H <sup>b</sup>	H	14 E <sub>2</sub>	200 TP	120
Synovex-H <sup>b</sup>	H	14 E <sub>2</sub>	200 TP	120
Component TE-200	S	20 E <sub>2</sub>	200 TBA	130
Revalor-200	S/H	20 E <sub>2</sub>	200 TBA	130
Synovex Plus	S/H	20 E <sub>2</sub>	200 TBA	130

<sup>a</sup> Adapted from: Campbell et al. (2005), CattleNetwork.com.

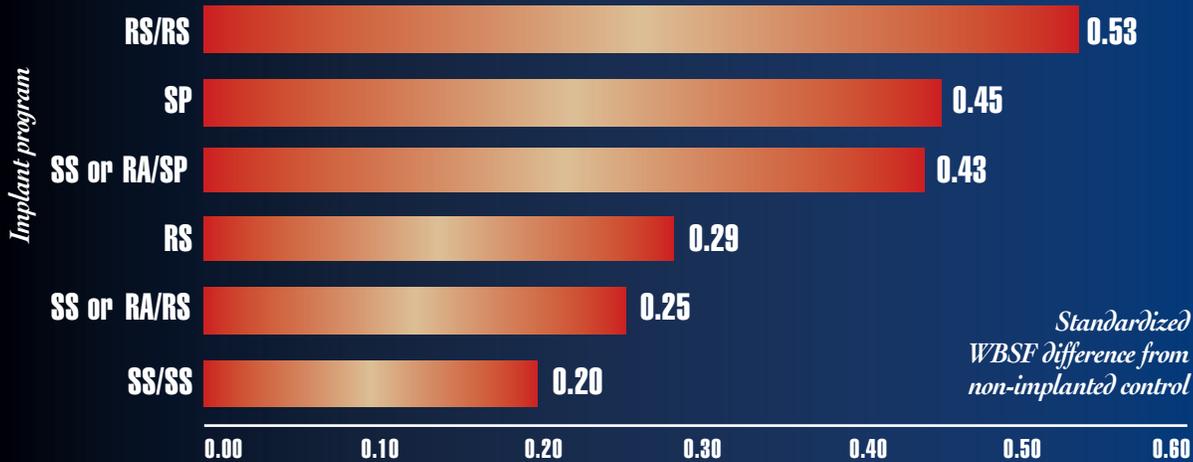
<sup>b</sup> Contains testosterone propionate (TP).

Implant products commonly administered to feedlot cattle during finishing are listed in Table 2. Heavy feeder cattle, scheduled to receive a single finishing implant, frequently are implanted with one of several relatively high-potency combination implants that contain both estrogen (E<sub>2</sub>) and trenbolone acetate (TBA). Single-implant programs for steers often involve the use of Component TE-S, Revalor-S, Component TE-200, Revalor-200, or Synovex Plus, whereas heifers receiving a single-implant frequently would be implanted with Component TE-H, Revalor-H, Revalor-200, or Synovex Plus. Steers scheduled to receive two successive finishing implants (implant/re-implant) typically receive an estrogenic implant (e.g., Ralgro, Component E-S, Synovex-S) or a low-dose combination implant (e.g., Component TE-IS, Revalor-IS, Synovex Choice) initially, followed by one of the higher-potency combination products (listed previously) as the terminal implant. Heifers implanted twice typically receive a low-dose combination implant (e.g., Component E-H, Synovex-H, Component TE-IH, Revalor-IH) initially, followed by a higher-potency combination terminal implant.

**Figure 3.**

**Effects of steer finishing implant programs on Warner-Bratzler shear force of the longissimus muscle**

(treatment effects are expressed as standardized mean differences from a non-implanted control)



Legend: RA = Ralgro, RS = Revalor-S; SP = Synovex Plus, SS = Synovex-S; "I" denotes initial implant/terminal implant

More aggressive two-implant programs, involving the sequential use of two high-potency combination implants, are sometimes used to maximize growth performance,<sup>51</sup> whereas cattle feeders who are most interested in enhancing quality grade performance often choose to use an implant/re-implant program that involves the use of two estrogenic or two sequential low-dose combination implants.

Recent studies investigating the effects of finishing implants on beef quality characteristics suggest that certain implant programs

may adversely affect product tenderness<sup>47, 52, 53</sup> and consumer acceptability.<sup>47, 54</sup> An analysis of published data from ten studies<sup>47, 53-61</sup> was conducted for this review and is summarized in Figure 3 to permit comparison of several of the more commonly used implant programs for finishing steers (too few studies involving heifers have been conducted to provide meaningful comparisons or recommendations). Values presented in Figure 3 are expressed as standardized mean differences in shear force between implant treatments and non-implanted controls and show the

relative effect of each implant program on beef tenderness. In the context of this analysis, values of 0.20 to 0.29 represent "small" increases in shear force, whereas values of 0.43 to 0.53 reflect "moderate" increases in shear force. These results demonstrate that careful use of finishing implants is essential for effective tenderness assurance, and suggest that implant programs for steers featuring a single mid-dose combination implant (24 mg E<sub>2</sub>, 120 mg TBA), two successive estrogenic implants (14 mg E<sub>2</sub>/14 mg E<sub>2</sub>), or an estrogenic implant (36 mg Zeranol or 14 mg E<sub>2</sub>)



followed by a mid-dose combination implant (24 mg  $E_2$ , 120 mg TBA) may be used without materially reducing tenderness (Figure 3). However, if the cattle feeder's goal is to minimize beef toughness problems, more aggressive implant programs, such as those involving a single high-dosage combination implant (20 mg  $E_2$ , 200 mg TBA), an implant/re-implant sequence including an estrogenic implant (36 mg Zeranol or 14 mg  $E_2$ ) followed by a high-dosage combination implant (20 mg  $E_2$ , 200 mg TBA), or two successive mid-dose combination implants (24 mg  $E_2$ , 120 mg TBA/24 mg  $E_2$ , 120 mg TBA) should be avoided (Figure 3).

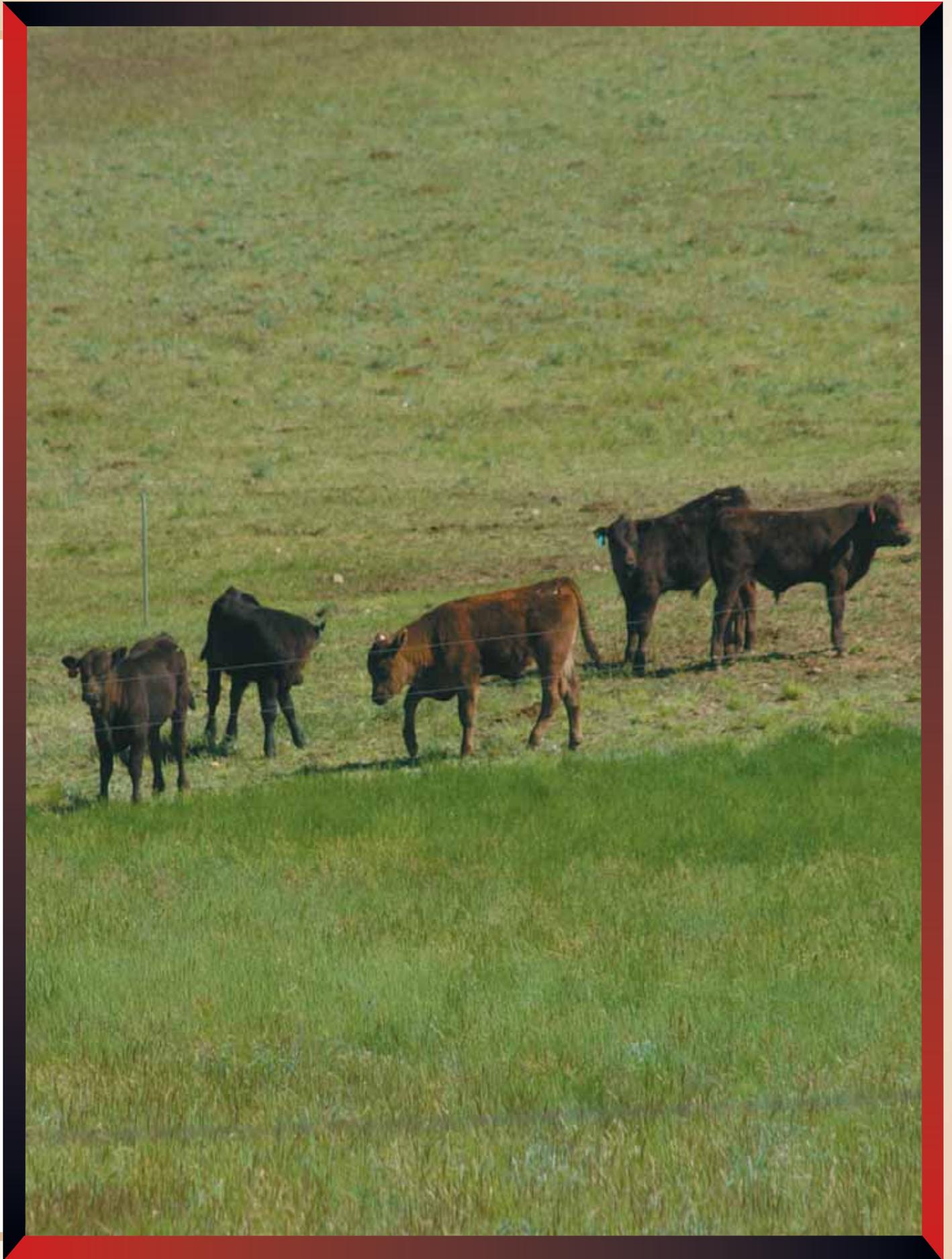
#### *Feed Additives.*

Supplementing finishing diets for heifers with melengestrol acetate (MGA) is a common practice in the

commercial feeding industry. Melengestrol acetate is an orally active progestin that, when included in the diets of heifers, suppresses estrus and improves growth performance.<sup>62</sup> Dietary supplementation with MGA increases circulating levels of estrogen in heifers, similar to the effect of implanting with a mild estrogenic implant. Correspondingly, MGA is particularly effective for enhancing growth performance of feedlot heifers implanted with androgenic implants. Nichols et al. (1996) reported data suggesting that including MGA in diets of feedlot heifers had no effect on WBS or trained sensory panel ratings for tenderness.<sup>63</sup> Heifers supplemented with MGA normally will show signs of estrus within 2 to 7 days of MGA withdrawal. The increased physical activity and stress associated with behavioral estrus in heifers, following MGA withdrawal, can result in an abnormally high incidence of dark cutting carcasses. Consequently, heifers should not be removed from MGA-supplemented diets for periods longer than 24 hours prior to harvest. In the U.S.,

MGA has no withdrawal requirement and may be fed until the time of shipment for subsequent harvest.

Optaflexx (the trade name for ractopamine hydrochloride) is a relatively new cattle feed ingredient designed to increase live weight gain, improve feed efficiency, and increase carcass yields of lean beef. Ractopamine hydrochloride is a beta-adrenergic agonist that is mixed into cattle finishing diets and provided to feedlot steers and heifers during the final 28 to 42 days before harvest. Research trials have shown that Optaflexx, when fed to steers at the recommended dosage of 200 mg/hd/d for the last 28 days of the finishing period, increases average daily gains by approximately 20% and improves feed efficiency (F/G) by almost 16%. In addition, Optaflexx supplementation (200 mg/hd/d) increases carcass weight, ribeye area, and carcass leanness (measured as % protein in the carcass), with little effect on marbling score, quality grade, carcass maturity, lean color, the incidence of "dark cutting" carcasses, or beef tenderness.<sup>64, 65</sup>



ADDITIONAL BEST  
MANAGEMENT  
PRACTICES FOR  
TENDERNESS  
ASSURANCE



**H** *Health Management and Husbandry.* Differences in costs associated with morbidity are the most important source of variation in profitability among groups of feedlot cattle,<sup>66</sup> which underscores the fundamental importance of effective cattle health-management programs. Morbidity during the finishing period (most frequently associated with bovine respiratory disease complex – BRD) depresses growth performance of finishing cattle, resulting in lighter carcass weights and lower marbling scores.<sup>67, 68</sup> In addition, Gardner et al. (1999) reported that cattle with respiratory tract lesions at the time of harvest produced tougher longissimus steaks (aged 7 days) than did cattle without lung lesions.<sup>67</sup> Correspondingly, effective tenderness management demands implementation of effective health management programs at all points in the beef chain.

Administration of animal health products via intramuscular (IM) injection can cause development of a lesion near the site of injection, which influences

tenderness of the surrounding muscle. An intramuscular injection causes trauma to the muscle at, and around, the injection site. Subsequent wound healing involves infiltration of connective tissue – which causes significant toughening of the surrounding muscle tissue – up to three inches from the center of the lesion.<sup>69</sup> Strict adherence to BQA guidelines for use of animal health products is advocated to avoid tenderness problems associated with IM injections.

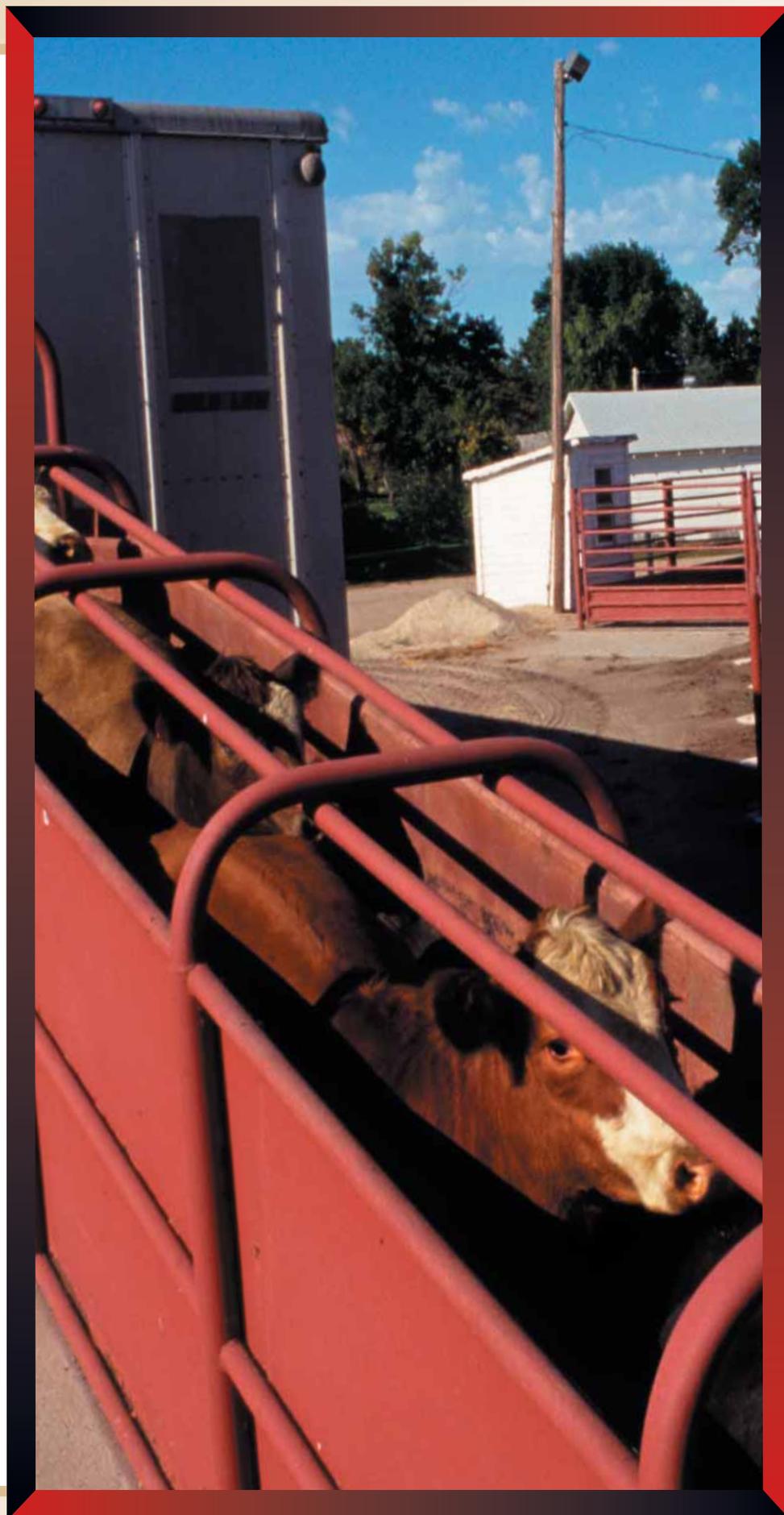
Timely application of routine management practices, such as castration of male calves, also can reduce variation in beef tenderness. To avoid sex-related beef tenderness problems, bull calves destined to become feeders should be castrated before they begin to develop the secondary sex characteristics of mature intact males.<sup>70</sup> The NCBA Beef Palatability Task Force recommendations issued in 1996 encouraged U.S. cattlemen to castrate bull calves prior to 7 months of age.<sup>71</sup>

### *Avoiding Pre-Slaughter Stress.*

Relationships between pre-harvest stress and meat quality characteristics have been recognized for many years. Pre-harvest stress, either acute or prolonged, depletes muscle glycogen stores, resulting in the production of beef with an abnormally high final muscle pH and a characteristically dark lean color (referred to as “dark cutting” beef).<sup>72, 73</sup> Pre-harvest conditions that cause any form of physical or psychological stress among cattle can result in muscle glycogen depletion and increase the incidence of dark cutting beef.

Common pre-harvest stressors in cattle include:

- a) aggressive handling, excitement, or physical exertion of cattle before, during, or following transport to the processing plant;
- b) long transit periods and (or) schedule delays preventing prompt unloading of cattle transported to processing plants;
- c) mixing of cattle from different sources before harvest, prompting physical activity as animals re-establish an order of social dominance within the mixed group;





- d) extremes in climatic conditions, including both extremely hot weather and cold, wet weather;
- e) extended fasting periods or prolonged feeding of very low-energy diets before harvest; and
- f) females exhibiting behavioral estrus near the time of harvest.

Carcasses produced by cattle subjected to pre-harvest stress exhibit varying degrees of the dark cutting condition, depending upon the extent of ante-mortem glycogen depletion and the final pH of the carcass musculature. Final muscle pH within a range of 5.4 to 5.7 is considered normal for beef. As muscle pH increases above 5.7, lean color becomes progressively darker. Beef carcasses with slightly higher-than-normal final muscle pH values, ranging from 5.8 to 6.2, exhibit a lean color that is only slightly dark; however,

a number of studies have shown that muscle pH values within this range are associated with a comparatively high frequency of meat toughness problems.<sup>74, 75</sup>

Cattle differ in behavior and temperament and, therefore, react differently when subjected to various pre-harvest stressors. Voisinet et al. (1997) determined that temperamental cattle produced carcasses with a very high (25%) incidence of a slightly dark lean color and longissimus steaks that were significantly tougher when compared with carcasses and steaks produced by calmer cattle.<sup>76</sup> More recently, Australian scientists have established a genetic relationship between “flight time” and beef tenderness. “Flight time” is an electronic measurement of the time required for an animal to travel a specified distance

(approximately 2 meters) after it leaves a squeeze-chute, and is related to the animal’s temperament (more excitable animals have faster flight times). Studies conducted by scientists at the Cooperative Research Centre for Cattle and Beef Quality have shown that “flight time” is moderately to highly heritable and has a relatively strong genetic correlation ( $r = -0.53$ ) with longissimus shear force. Interestingly, phenotypic correlations between “flight time” and measures of tenderness were found to be very low, which led the researchers to conclude that “best practice” handling might overcome tenderness problems associated with poor temperament and pre-harvest stress.<sup>77</sup> Adopting management practices that reduce handling and environmental stress and preferential selection of cattle with calm temperaments are essential elements of effective beef quality management systems. Meat & Livestock Australia (2000) offers cattle producers a very useful set of practical guidelines for avoiding beef quality problems caused by pre-harvest stress.<sup>78</sup>

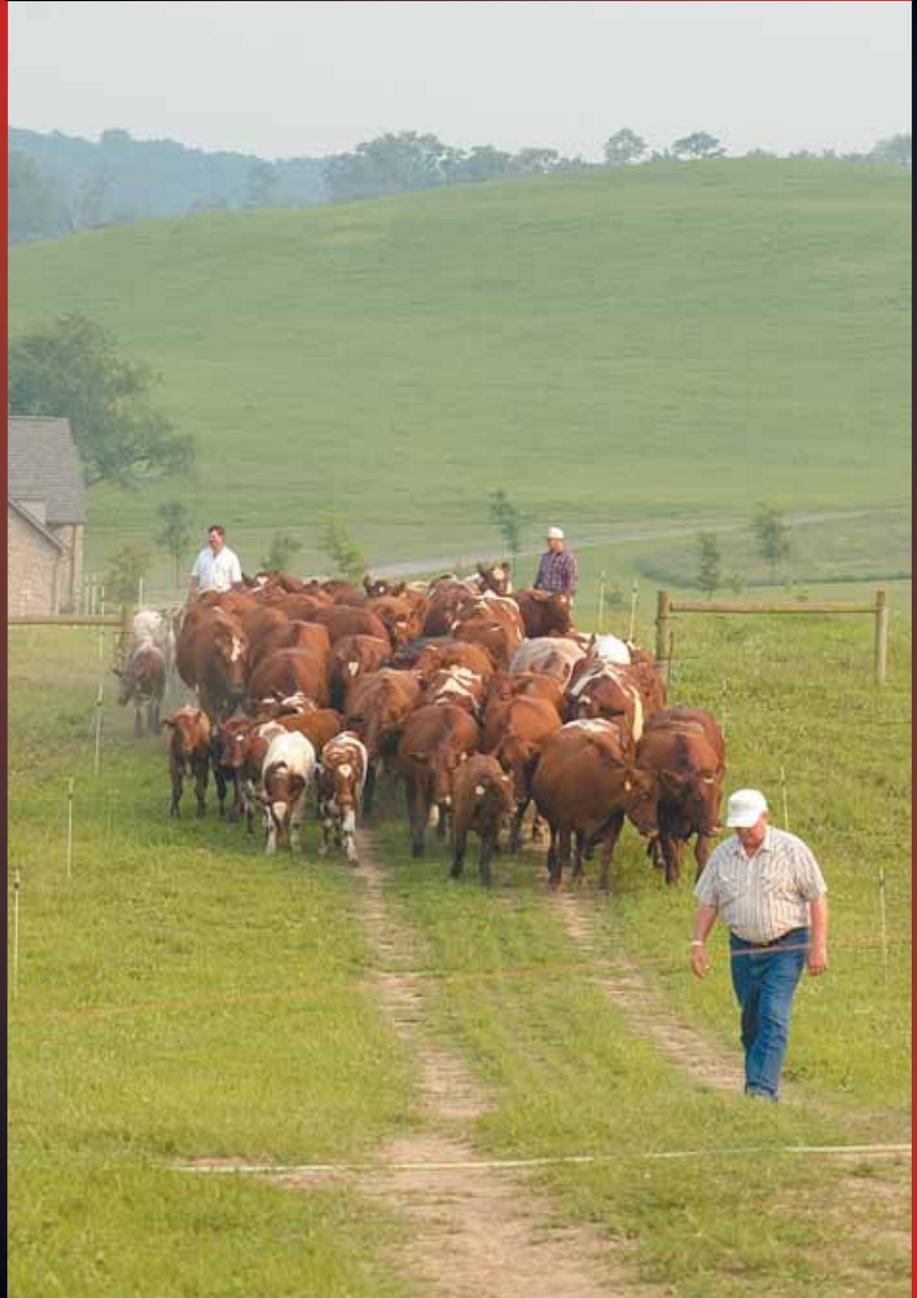


for beef. Beef consumers associate eating satisfaction with product value and many are willing to pay premium prices for beef with the level of tenderness or the flavor characteristics they prefer.<sup>81-84</sup>

## THE IMPORTANCE OF BEEF PRODUCERS' EFFORTS TO MANAGE BEEF TENDERNESS



Delivering a quality eating experience is essential to the continued success of the beef industry's efforts to build consumer demand for beef products.<sup>79</sup> Consumer survey results suggest that eating quality (defined by most consumers simply as "taste") is a primary driver of food purchase decisions across a variety of product categories<sup>80</sup> and experimental market research has established a direct link between the eating qualities (tenderness and flavor) of beef and actual purchase behavior of beef consumers.<sup>81-84</sup> These findings are significant to the beef industry because they provide compelling evidence, suggesting that efforts to improve the eating qualities of beef, if successful, will not only increase the likelihood that a consumer will purchase a beef product, but also can increase the prices that shoppers are willing to pay



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6-2006 2,000 ITEM#12811