Producing Flavorful Beef

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Beef's Great Taste – Importance of Beef Flavor

Great taste is the primary reason consumers frequently make beef their food of choice for a pleasurable dining experience. Research conducted to examine consumers' preferences for various protein sources (beef, chicken, fish, pork, shellfish) has shown that a pleasurable eating experience is the number-one driver of protein preference, whether dining at home or in a restaurant (NCBA, 2006). In a 2006 investigation of factors influencing beef purchases (Reicks, 2006), consumers were asked to rate the importance of nine different product attributes (tenderness, juiciness, flavor, product consistency, ease of preparation, nutritional value, natural, organic, and price) when making beef purchase decisions. In that study, the most important "purchasing motivators" were (1) taste attributes, (2) price, and (3) product consistency (Reicks, 2006). Similarly, Moeller and Courington (1997) found that consumers rated attributes related to the eating experience (i.e., flavor, tenderness, meal enjoyment, and consistent quality) as most important when purchasing beef. Delivering a desirable eating experience time-after-time is fundamentally important to sustained growth in beef demand (Schroeder and Mark, 2000).

Consumers' overall perceptions of the taste of beef are based on a combined assessment of three primary sensory attributes – tenderness, juiciness, and flavor (Neely et al., 1998). While tenderness is most often cited as the fundamental determinant of a beef product's performance with respect to eating quality (Huffman et al., 1996; Miller et al., 2001; Platter et al., 2003), the contribution of beef's distinctive flavor to the overall eating experience may be increasing in importance (Felderhoff et al., 2007). The 2006 National Beef Tenderness Survey (NBTS) evaluated over 2,100 beef steaks from retail and foodservice establishments in 11 different U.S. cities (Voges et al., 2007). Of the steaks evaluated in the 2006 NTBS, more than 96% were found to be "tender" or "very tender" based on Warner-Bratzler shear force measurements – a marked improvement when compared with results of previous tenderness surveys (Voges et al., 2007). Recent consumer research has shown that once tenderness is within an acceptable range, or when variation in tenderness has been minimized, then flavor becomes the most important determinant of beef consumers' assessments of overall satisfaction (Goodson et al., 2002; Killinger et al., 2004a; Behrends et al., 2005a; Behrends et al., 2005b). Continued industry efforts to improve beef tenderness, if successful, will cause flavor to become increasingly important to discriminating beef consumers.

The importance of beef flavor in the marketplace is underscored by the fact that consumers' flavor preferences are reflected in their beef purchase decisions (Killinger et al., 2004a, b; Sitz et al., 2005). Research conducted at Colorado State University (Platter, 2003) utilized experimental auction techniques to examine the relationships of beef quality attributes to consumers' purchasing behavior and to prices they were willing to pay for beef. In that study, consumers (representative of primary U.S. population demographics) evaluated the sensory properties of beef strip loin steaks of various quality levels. After consumers had evaluated the steaks, they were asked, without obligation, to participate in a sealed-bid Vickrey auction in which they could purchase steaks identical to those they had sampled (i.e., their purchase decisions were based on their own first-hand assessments of product performance with respect to eating quality). Two very important relationships between beef flavor and purchasing behavior were revealed: (a) flavor desirability ratings were directly related to the probability that consumers would bid to purchase a steak (Figure 1), and (b) average bid prices for steaks increased as flavor desirability ratings improved (Figure 2). These findings suggest that <u>if beef tastes great</u>, people not only are <u>more likely to buy</u> it, but also <u>will pay more</u> for it.

Flavorful Beef Starts at the Producer-Level

Providing consumers with a desirable beef eating experience, on a consistent basis, requires the coordinated efforts of participants along the entire beef chain, beginning with the producer. Research has shown that the eating qualities of beef are influenced by a variety of pre-harvest factors (both genetic and environmental) and that systematic control of cattle production and management practices can enhance palatability of the final product (Tatum, 2006). To date, efforts to manage beef palatability attributes at the producer-level have focused specifically on pre-harvest management of beef tenderness (Tatum et al., 1999). A more thorough understanding of pre-harvest management practices that lead to production of consistently flavorful beef would further assist cattle producers in their ongoing efforts to build beef demand and add value to cattle. Several primary factors that contribute to differences in the flavor of cooked beef, and are subject to management at the producer-level, are identified and discussed below.

Marbling and Beef Flavor

Pre-harvest factors that influence beef flavor do so primarily via effects on amount and composition of fat. Lipids and the volatile compounds they produce during cooking are major contributors to the odor and flavor of meat (Wood et al., 2003; Calkins and Hodgen, 2007). Correspondingly, cattle production systems that encourage deposition of intramuscular fat (IMF) are fundamentally important for development of desired beef flavor characteristics (Ritchie, 2005).

Data reported by Smith et al. (1983) suggest that beef flavor desirability of strip loin steaks increases as the concentration of extractable IMF increases up to approximately 10.5% IMF (Figure 3). Likewise, Thompson (2004) characterized the relationship between IMF content (measured using near-infrared spectroscopy) and Australian consumer sensory scores for flavor (like/dislike) of beef strip loin steaks. After adjusting for peak shear force to remove the effect of tenderness, a curvilinear relationship between % IMF and flavor score was observed; flavor desirability increased as % IMF increased, reaching a plateau at about 14% IMF (Thompson, 2004). For reference, 10.5% extractable fat in the rib eye at the 12th rib would correspond to a USDA marbling score of Moderately Abundant, while 14% IMF would be beyond the upper boundary (approximately 12% IMF) of the Abundant marbling score in the USDA grading system (Savell et al., 1986).

Carcass marbling score (assessment of the amount and distribution of visible flecks of intramuscular fat in the ribeye at the 12th-13th rib interface) is a primary factor used to determine USDA quality grades for beef carcasses and is positively associated with consumer acceptance of beef, due in-part to its effect on beef flavor (Platter et al., 2003). Research has shown that flavor desirability ratings for the beef longissimus muscle increase linearly as marbling score increases from Practically Devoid to Moderately Abundant (McBee and Wiles, 1967; Smith et al., 1980). It is important to note, however, that the relationship between carcass marbling score and flavor is important primarily for beef cuts derived from the rib and loin (Smith et al., 1980; Neely et al., 1998). Variation in carcass marbling score (assessed in the ribeye) has much less influence on flavor desirability of beef cuts from the round (Smith et al., 1980; Neely et al., 1998) and chuck (Goodson et al., 2002).

Smith et al. (1983), following a review of the relationship between marbling and beef flavor, concluded that marbling score (as used in the application of USDA grades for beef carcasses) indirectly assesses concentrations of flavor/aroma compounds in beef and that carcasses with high levels of marbling have a greater likelihood of producing meat that tastes "beefy" and is more desirable in flavor. The importance of carcass marbling score for ensuring flavor desirability of beef strip loin steaks is highlighted in Figure 4. Data summarized in Figure 4, show that the incidence of undesirable flavor ratings decreases dramatically as marbling score increases, from more than 55% undesirable ratings at a marbling score of Practically Devoid to zero undesirable ratings at a marbling score of Moderately Abundant (Figure 4). Moreover, once marbling scores of Modest or greater are attained, the incidence of undesirable flavor ratings is greatly diminished (less than 5% in Figure 4).

Research findings summarized above suggest that producing cattle with relatively high marbling levels (i.e., Modest or greater) generally improves beef flavor and increases the likelihood of a pleasurable eating experience. The ability of cattle to express their genetic potential for deposition of marbling, however, can be impaired by numerous non-genetic factors (Corah and McCully, 2006). Studies have shown that morbidity (McNeill et al., 1996), delayed castration of male calves (Heaton et al., 2004), restriction of dietary energy during early stages of growth

(Miller et al., 1987), and aggressive use of growth enhancement technologies (Duckett and Andrae, 2001) can all have detrimental effects on marbling and, therefore, may potentially affect beef flavor characteristics.

For example, growth enhancement technologies (hormonal implants and feed additives containing beta agonists) do not appear to have a direct effect on beef flavor. Yet, aggressive use of growth enhancement products can limit intramuscular fat deposition, thereby affecting beef flavor desirability. Platter et al. (2003) found that beef produced by non-implanted steers was rated as more desirable in flavor compared with beef from implanted steers. However, when comparisons were made at a constant marbling score, flavor desirability ratings were similar for steaks from implanted and non-implanted cattle (Platter et al., 2003). If the goal is to produce beef with exemplary flavor, then production systems and management practices known to negatively affect marbling deposition should be avoided.

Effects of Diet and Time-On-Feed

Grain-Fed vs. Grass-Fed Beef. Studies comparing quality characteristics of forage-fed and grain-fed beef suggest that feeding grain to cattle improves beef flavor (Schroeder et al., 1980; Bowling et al., 1978; Hedrick et al., 1983). Moreover, research has shown that the majority of U.S. consumers are able to detect the difference in flavor between grain-fed and grass-fed beef and prefer the flavor characteristics of beef produced by grain-finished cattle. Killinger et al. (2004b) conducted a beef marketing study involving consumers in Chicago and San Francisco, in which U.S. corn-fed beef was compared with Argentine grass-fed beef. Shear force and marbling were held constant in these comparisons to isolate the effects of flavor on consumer preference. Consumers in both cities rated U.S. corn-fed beef higher in flavor desirability and overall acceptability than Argentine grass-fed beef. Overall, 60% of consumers preferred the flavor of corn-fed beef, 18% preferred the flavor of grass-fed beef, and 22% had no preference for either product (Killinger et al., 2004b). A similar study, conducted by Sitz et al. (2005) with consumers in Chicago and Denver, compared U.S. grain-fed beef with Australian grass-fed beef. Once again, matched steaks with similar marbling scores and shear force values were used. In the latter study, 64% of consumers preferred the flavor of domestic grain-fed beef, 19% preferred the flavor of Australian grass-fed beef, and 16% expressed no preference (Sitz et al., 2005). In both studies, consumers demonstrated a willingness to pay higher average prices for steaks from grain-fed cattle, based on flavor preference (Killinger et al., 2004; Sitz et al., 2005).

Compared with beef from cattle finished on grain diets, beef produced by cattle finished on forages has different concentrations of several flavor precursors the most important of which reside in the fat tissue (Melton, 1990). Forage-finished beef has higher levels of linolenic and other n-3 polyunsaturated fatty acids, whereas grain-finished beef contains higher concentrations of oleic and n-6 polyunsaturated fatty acids, particularly linoleic acid (Elmore et al., 2004; Calkins and Hodgen, 2007). Mandell et al. (1998) compared the effects of forage vs. grain feeding on fatty acid composition and beef flavor characteristics and concluded that a significant proportion of the difference in flavor between grain-fed and forage-fed beef was due to the higher levels of oleic acid (and its derivatives) in grain-fed beef compared with higher levels of linolenic acid (and its derivatives) in forage-fed beef.

Sensory panelists often characterize the less desirable flavor of forage-fed beef as "grassy," "dairy/milky," "gamey," or "fishy" compared with the "beef fat" flavor normally associated with grain-fed beef (Melton et al., 1982a, b; Larick and Turner, 1990). High levels of linolenic acid in beef have been found to produce flavors characterized as "grassy" and "fishy" (Wood et al., 2003). In addition, Larick et al., (1987) identified 14 different compounds in the volatiles of melted subcutaneous fat of forage-fed cattle, which were positively correlated with "grassy" flavor of beef loin steaks. The compound most closely correlated with "grassy" flavor in their study was a phyt-2-ene, a diterpenoid derived from breakdown of chlorophyll. In contrast, 2 lactones, δ-tetradecalactone and δ-hexadecalactone, were negatively correlated with "grassy" flavor (Larick et al., 1987). Maruri and Larick (1992) subsequently determined that lactones are associated with the "roasted beef flavor" of grain-fed beef, whereas diterpenoids are associated with an off-flavor of grass-fed beef described by sensory panelists as "gamey/stale." Scientists at the University of Tennessee isolated several volatiles that were associated with flavor differences between grass-fed and grain-fed beef and were able to effectively mimic the characteristic "beef fat" flavor of grain-fed ground beef by spiking ground beef from forage-fed cattle with low levels of pentanal, toluene, and m-xylene (Melton, 1990). Numerous other volatiles have been identified, which also may contribute to the distinct flavor profiles of grass-fed and grain-fed beef (Elmore et al., 2004; Brewer, 2006; Calkins and Hodgen, 2007).

***Time-On-Feed*.** Cattle that are grown on relatively low-energy forage diets must be fed grain for a sufficient period of time before harvest to develop the beef flavor characteristics that consumers commonly associate with those of grain-fed beef. Harrison et al. (1978) reported that the flavor of cooked beef fat became more desirable as length of the grain-feeding period increased (from 0 to 98 days on feed). In addition, Larick et al. (1987) determined that sensory panel scores for "grassy" flavor of steaks and ground beef decreased steadily with increased time on a grain diet (from 0 to 112 days on feed). Melton et al. (1982b) studied flavor changes in ground beef during a 140-d finishing period, and found that intensity of "beef fat" flavor (characteristic of grain-fed beef) increased, whereas intensity of flavors characterized as "milky-oily," "sour," and "fishy" (which sensory panelists associated with grass-fed beef) decreased as time on feed increased (Figure 5). Data summarized in Figure 5 (Melton et al., 1982b), together with results reported by Harrison et al. (1978) and Larick et al. (1987), suggest that most of the changes in beef flavor occur within the first 84 to 112 days of the grain-finishing period. In general, grain-finishing periods of approximately 100 days or longer have been shown to be effective for developing the desirable flavor characteristics typically associated with grain-fed beef (Tatum et al., 1980; Dolezal et al., 1982).

Time-on-feed varies with the age and weight at which cattle are placed on a high-concentrate finishing diet. Weaned calves, entering the feedlot at ages of 6 to 9 months of age, typically are fed for periods of 150 to 210 days and harvested at approximately 12 to 15 months of age, whereas stocker cattle placed on feed as yearlings (≥ 12 months old) typically are fed for periods of 90 to 150 days and usually are about 16 to 20 months old at harvest. Brewer et al. (2007) compared calf- and yearling-finished steers fed high-concentrate finishing diets for 191 and 91 days, respectively. In that study, calf-finished steers were harvested at 13 to 14 months of age, while yearling-finished steers were 19 to 20 months old at harvest. Steaks produced by calf-finished steers received higher mean sensory ratings for flavor and were less likely to be rated as "undesirable" in flavor compared with steaks from yearling finished steers (Brewer et al., 2007). Results of other studies, however, suggest that flavor characteristics of beef produced by calf-fed vs. yearling-fed cattle do not differ (Lunt and Orme, 1987; Johnson et al., 1990; Harris et al., 1997).

Source of Dietary Energy. Though corn is the predominant cereal grain used in cattle finishing diets throughout the high-plains region of the U.S., barley is used extensively for finishing cattle in western Canada (Beauchemin and Koenig, 2005) and the northern U.S. (Lardy and Bauer, 1999) and feeders in the southern high-plains often replace corn with sorghum grain (milo). Interestingly, only a few studies have compared flavor characteristics of beef produced by cattle finished on corn vs. various other grains. Brandt et al. (1992) compared sensory properties of beef produced by cattle finished on diets containing steam-flaked sorghum grain vs. steam-flaked corn and determined that beef produced using corn and sorghum grain had similar flavor characteristics. Similarly, Miller et al. (1996) reported that grain type (corn vs. barley) had no effect on flavor characteristics of beef. In contrast, Jeremiah et al. (1998) and Busboom et al., (2000) both found that beef produced by cattle fed barley had slightly less desirable flavor characteristics than beef from corn-fed cattle. In the latter two studies, feeding cattle barley-based diets produced beef with a metallic aftertaste (Jeremiah et al., 1998; Busboom et al., 2000). The difference in flavor of beef produced by cattle fed corn vs. those fed barley apparently is large enough to be detected by consumers. Sitz et al. (2005) compared consumer's assessments of U.S. corn-fed beef and Canadian barley-fed beef and found that consumers in Chicago and Denver preferred the flavor of U.S. corn-fed beef. Moreover, based on their flavor preference, consumers demonstrated a willingness to pay a higher average price for corn-fed beef (Sitz et al., 2005).

Use of ethanol co-products in cattle finishing diets has increased in recent years due to the rapid expansion of the corn-based ethanol industry and resultant increases in corn prices. Cattle feeding trials conducted at several universities suggest that feeding wet or dry distillers grains at high levels (over 30%, DM basis) during finishing may, in some cases, reduce marbling deposition (Corah and McCully, 2006; VanOverbeke, 2007). Scientific information concerning the effect of feeding distillers grains on beef flavor is extremely limited. Roeber et al. (2005) reported that feeding diets containing up to 40% dry distillers grains (DDG) or up to 50% wet distillers grains (WDG) had no effect on beef flavor characteristics. Similarly, Jenschke et al. (2007) finished cattle with diets containing up to 50% WDG and observed no detrimental effects on beef flavor. More recent research suggests that feeding 30% WDG alters fatty acid profiles of beef, which could lead to development of off-flavors (Mello, Jr. et al., 2007), though no direct evidence linking WDG feeding with changes in beef flavor has been reported. Correspondingly, apart from its possible negative effect on marbling, the practice of feeding distillers grains does not appear to influence beef flavor.

Inclusion of potato by-products in cattle diets is a common practice in northwestern U.S. feedlots (Nelson et al., 2000). Busboom et al. (2000) and Radunz et al (2003) compared sensory properties of beef from cattle finished with and without potato by-products and found no meaningful differences in beef flavor characteristics. Moreover, Busboom et al. (2000) reported that consumer acceptability of beef was not affected by feeding of potato by-products.

Effects of Breed and Genotype

Scientific evidence suggests that non-genetic effects, such as pre-slaughter diet, have much greater influence on beef flavor than do additive and non-additive genetic effects (Gregory et al., 1994). Heritability estimates reported for beef flavor intensity (Gregory et al., 1994; Wheeler et al., 2001; Riley et al., 2003; Nephawe et al., 2004; Dikeman et al., 2005) typically have been very low (0.04 to 0.07), suggesting that less than 10% of the variation in beef flavor may be attributed to additive genetic effects. Even though a few reports (Wheeler et al., 2004, 2005) indicate that beef flavor may be moderately heritable (h^2 = 0.26 to 0.40), direct selection for improved flavor characteristics is impractical due to the difficulty and cost of measuring phenotype. Additionally, comparisons across a broad spectrum of cattle breeds and biological types have revealed few meaningful differences in beef flavor (Koch et al., 1976, 1979, 1982; Wheeler et al., 1996, 2001, 2004, 2005), suggesting that preferential use of specific breeds to improve beef flavor has limited potential.

The minor among-breed flavor differences that have been documented (Figure 6) tend to be moderately correlated with breed differences in marbling (Gregory et al., 1994). Marbling is a moderate to highly heritable trait (Ritchie, 2005). Furthermore, moderate to strong, positive genetic correlations of marbling and(or) % IMF with beef flavor have been reported (Gregory et al., 1994; Riley et al., 2003; Wheeler et al., 2001; 2004; 2005). Genetic relationships between beef flavor and marbling (or %IMF) suggest that selection of cattle for increased marbling or IMF would result in gradual improvement of beef flavor.

Effects of Pre-Harvest Stress and Cattle Temperament

Subjecting cattle to different levels of handling stress immediately before slaughter has been shown to affect beef flavor characteristics (Jeremiah et al., 1988). Stressful events, whether physical, emotional, or environmental, deplete muscle glycogen, causing an abnormally high final muscle pH and a dark, purplish-red lean color (commonly termed “dark cutting” beef). Wulf et al. (2002) compared palatability characteristics of several muscles from normal vs. dark cutting carcasses and found that strip loin and top sirloin steaks from dark cutting carcasses received lower flavor desirability ratings than did comparable steaks from normal carcasses (Figure 7). In addition, compared with steaks from normal carcasses, steaks from dark cutting carcasses had a higher incidence of off-flavors described by sensory panelists as "peanutty," "sour," and "bitter"(Wulf et al., 2002). Adopting management practices that minimize pre-slaughter stress have been shown to reduce the incidence of off-flavors and improve desirability of beef flavor (Jeremiah et al., 1988).

Cattle differing in disposition react differently to pre-harvest stressors. Temperamental cattle not only are more likely to produce dark cutting carcasses (Voisinet et al., 1997), but also have been shown to produce carcasses with lower marbling scores (Busby et al., 2006), both of which can negatively influence beef flavor.

Voisinet et al. (1997) determined that heifers are more excitable than steers and, therefore, are more likely to produce carcasses with dark cutting characteristics. Wulf et al. (1997) also reported that heifers were more temperamental than steers and presented data showing that cattle temperament score was significantly correlated with several longissimus muscle characteristics including muscle color and sensory panel ratings for both tenderness and flavor. In that study, cattle with more excitable temperaments had higher final muscle pH measurements, darker muscle color, and lower sensory panel ratings for flavor and tenderness compared with cattle having calmer temperaments (Wulf et al., 1997). These findings highlight the importance of gentle handling of slaughter cattle (especially heifers) during transport and immediately before harvest for assurance of final product quality.

Busby et al. (2006) compared carcass quality grades of cattle differing in disposition (Figure 8) and found that cattle classified as "docile" produced a higher percentage of carcasses grading U.S. Choice or Prime (74%) compared with cattle with "aggressive" temperaments (58%). In addition, the Certified Angus Beef® acceptance rate for "docile" cattle (29%) was approximately twice the rate (14%) recorded for "aggressive" cattle (Busby et al., 2006). Results of several studies suggest that cattle temperament is moderately heritable (Schmutz et al., 2001). Consequently, effective selection of cattle for docility could produce beneficial effects on several beef quality traits, including color, marbling, tenderness, and flavor.

Key Points: Producing Consistently Flavorful Beef

- Production/management factors that influence beef flavor do so primarily via effects on amount and composition of fat.
- Beef flavor desirability increases as intramuscular fat content increases. Marbling scores of Modest or greater provide the greatest assurance of desirable beef flavor characteristics.
- If the goal is to consistently produce beef with exemplary flavor, then management practices that have been shown to reduce marbling deposition (e.g., ineffective animal health programs, delayed castration of male calves, restriction of dietary energy during the

growing period, aggressive use of growth enhancement technologies) should be avoided. In addition, selecting cattle for increased levels of marbling or IMF would, over time, result in favorable effects on beef flavor.

- Grain feeding improves beef flavor. In general, grain-finishing periods of approximately 100 days or longer are effective for developing the desirable beef flavor characteristics commonly associated with grain-fed beef. Moreover, corn-based diets seem to produce beef with flavor characteristics preferred by most U.S. consumers.

- Pre-slaughter stress, resulting in dark cutting beef, has a negative effect on beef flavor. Therefore, adoption of cattle handling practices that minimize pre-slaughter stress is important for assurance of a pleasurable eating experience.

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Figure 1. Relationship between consumer flavor rating and probability of consumers bidding to purchase striploin steaks

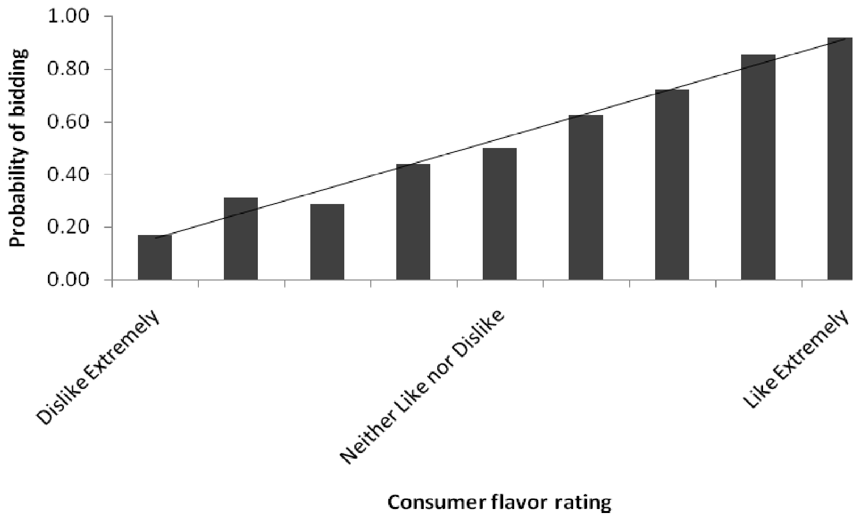

Figure 2. Relationship between consumer flavor rating and average bid price for striploin steaks

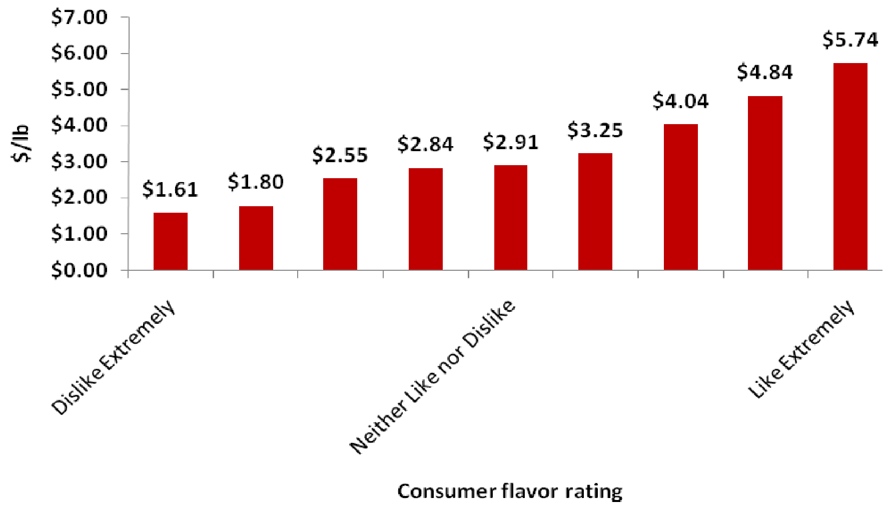

Figure 3. Relationship between percentage of extractable intramuscular fat in the longissimus muscle and sensory ratings for beef flavor desirability

Source: Smith et al. (1983)

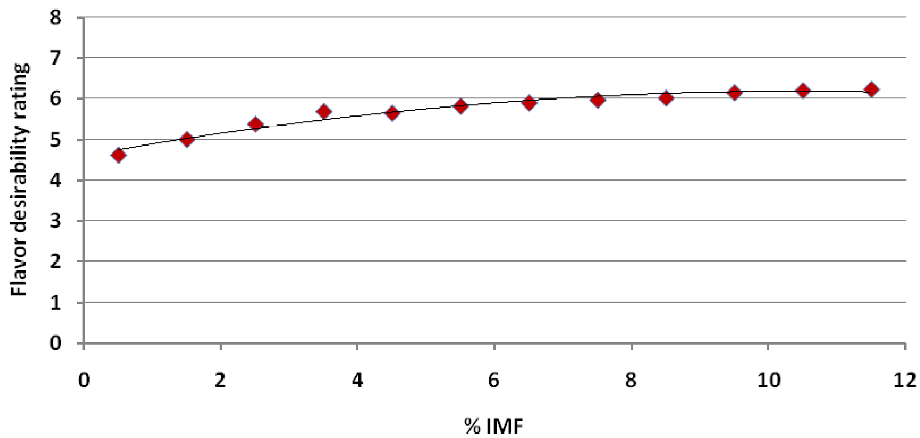

Figure 4. Relationship between marbling score and the frequency of undesirable flavor ratings

Source: Smith et al. (1980)

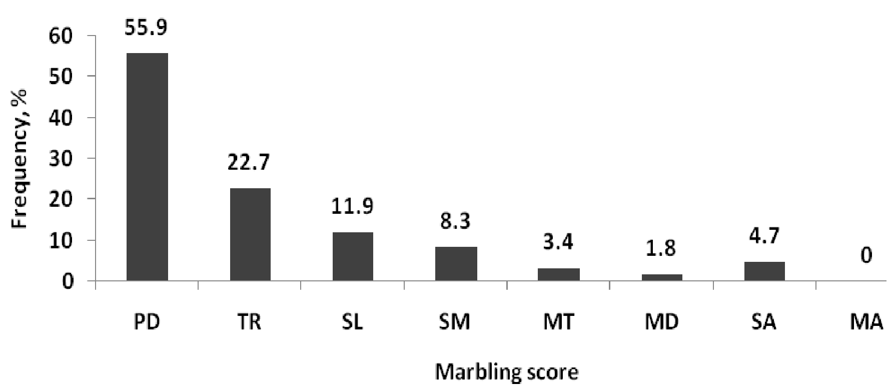

Figure 5. Relationship between days on feed and beef flavor characteristics

Source: Melton et al. (1982b)

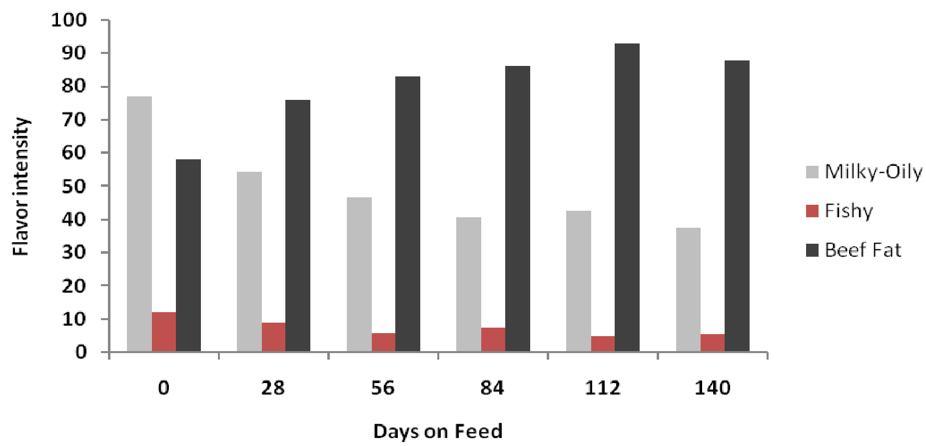

Figure 6. Relationship Between Marbling and Beef Flavor Among Major U.S. Beef Cattle Breeds

Source: Wheeler et al. (2001, 2005)

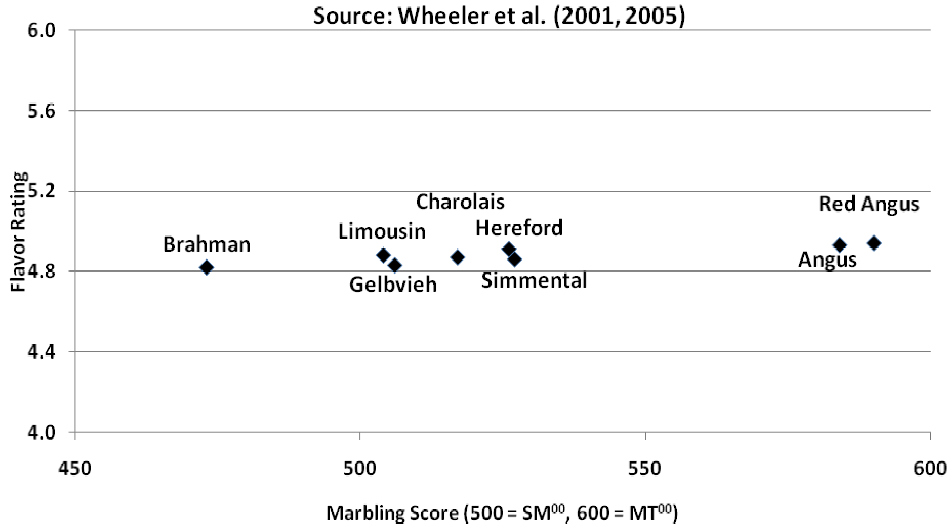

Figure 7. Flavor desirability ratings for steaks from normal vs. dark cutting beef carcasses

Source: Wulf et al. (2002)

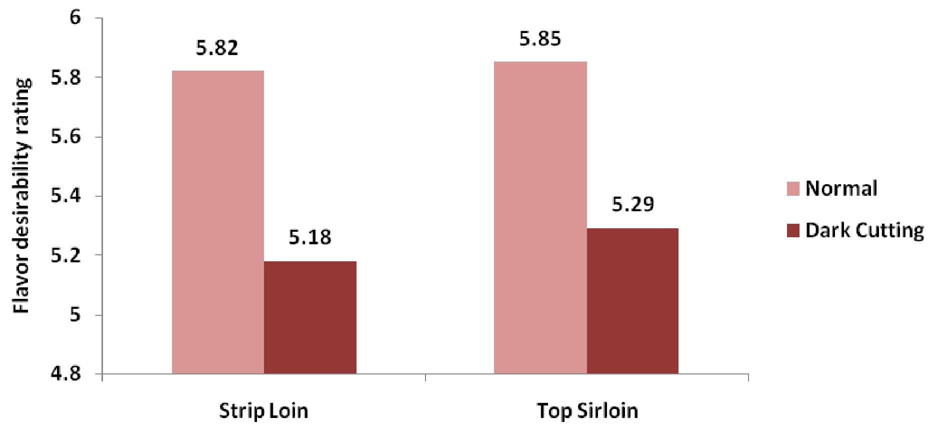

Figure 8. Effect of Cattle Temperament on USDA Quality Grade and CAB Acceptance Rate

Source: Busby et al. (2006)