The Pennsylvania State University
The Graduate School
Department of Dairy and Animal Science

ANALYSIS OF GRASS-FINISHED BEEF
PRODUCTION BENCHMARKS FOR NORTHEASTERN GRASS-FED BEEF FARMS

A Thesis in
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by
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Twenty grass-finished steers and 10 grass-finished heifers were evaluated for the relationship of daily BW gain, sex, grazing period, frame size (Beef Improvement Federation, 2002), final weight, and carcass traits (fat thickness, ribeye area, marbling score, and yield grade). Consumers also evaluated tenderness, juiciness, flavor, texture, and acceptability of cooked steaks from these animals. All of the cattle were wintered for a targeted weight gain of 0.73 kg/d for 156 d postweaning and then were maintained in rotationally-grazed paddocks containing primarily cool-season grasses. Cattle were harvested at a constant age (532.9 d ± 5.7 d) in 6 harvest groups ranging from 124 d to 187 d of grazing and carcass data were collected.

Six longissimus muscle steaks were taken from each of the thirty carcasses and consistently labeled for position on the 9th to 12th rib section of the longissimus muscle. One of the steaks from each of the carcasses was evaluated for tenderness using the Warner Bratzler shear force test. An additional steak from each of the thirty carcasses was thawed, cooked and offered to consumer panelists. A longissimus muscle steak was to determine the total lipid, fatty acid content for each of the steaks.

Correlations were determined on the relationship of animal, production, and carcass traits with the consumer evaluations, the relationship of fatty acids and cholesterol with consumer evaluations, and the relationship of production and carcass traits with fatty acid and cholesterol profile. Results indicated animal factors, growth rate, and carcass traits were not strongly related to panelist evaluations of tenderness, flavor, juiciness, meat texture, or overall desirability for grass-finished cattle harvested at 533 d of age. Significant variation in scores for tenderness, juiciness, texture, flavor, and overall desirability were found and animal, growth, and carcass
traits were not strongly related with the fatty acids and cholesterol for grass-finished cattle harvested at 532 d of age.

Twenty-six grass-fed beef producer were surveyed to evaluate an annual cash flow. Most of the producers reported that their cattle graze forages with grass/legume combinations (mean = 61.1%). The mean age at harvest was 21.4 mo with a minimum age of 14 mo and a maximum age of 27 mo. The mean weight was 498 kg, the mean cost of production per steer was $1,706.02, with a breakeven value of $3.43/kg. Correlations were calculated on net returns to land and labor and gross income with cost of equipment, purchased feed, land and cost per steer. Lowering the equipment, purchased feed, and land costs, while increasing the returns per steer, may improve net returns to land and labor and gross income of the farm.

(Keywords: Grass-fed, beef, carcass traits, production, economics)
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Chapter 1

REVIEW OF LITERATURE

1.1 Carcass traits

Carcasses are evaluated to predict the amount of retail cuts available from the whole carcass and the palatability of the lean. In order to make these predictions, expert graders examine the carcass for certain characteristics. These traits include subcutaneous fat thickness, percentage of kidney, pelvic, and heart fat (% KPH), rib-eye area (REA), hot carcass weight (HCW), maturity, color and texture of the lean, and the degree of marbling.

1.1.1 Fat thickness

Fat thickness is the depth of fat over the longissimus muscle at the 12th rib. This thickness is estimated about 114.3 -127 mm from the dorsal midline, which approximates a point that is ¾ of the lateral length of the longissimus muscle from the split chine bone at the 12th rib. The fat thickness can be extreme (1-28 mm), normal (4-20 mm for steers and heifers and 1-13 mm for Bullocks), and average (13 mm for Choice steers and heifers and 9 mm for bullocks). A minimum of 5 mm of fat at the 12th rib is necessary to protect the carcass from excessive shrinkage, discoloration, and loss of bloom during storage and handling (Boggs et al., 2006). The target for fat thickness in the carcass is 10-13 mm (Boggs et al., 2006). Fat thickness can be adjusted upward or downward to reflect unusual amounts of fat in areas such as the brisket, plate,
flank, cod or udder, inside rump and hips in relation to the actual fat thickness over the rib-eye
(Boggs et al., 2006). Fat thickness at the 12th rib also is a factor used to calculate the yield grade.
As the amount of external fat increases, the yield grade increases numerically toward 5 and the
percentage of boneless, closely trimmed retail cuts decreases (Boggs et al., 2006).

Tatum et al. (1982) used yearling and long-yearling steers (n = 471) and fed them
identical grain-finishing diets for 100, 130, and 160 d at a commercial feedlot. It was found that
marbling accounted for about 5, 5, 15, and 9% of the variation in trained sensory panel ratings
for juiciness, overall tenderness, flavor desirability and overall palatability, respectively.
Marbling was found to be related positively to palatability and all the relationships were highly
significant (P < .01); however, the magnitude of the regression coefficients suggested that large
differences in marbling would be required to result in changes for palatability. Although the
degree of association between marbling and cooked beef palatability was low, marbling level
was found to be effective at identifying steaks as “desirable” or “undesirable.” More than 92, 99
and 92% of the steaks having “slight” or higher degrees of marbling were found to be “desirable”
for overall tenderness, flavor, and palatability, respectively. Regarding fat thickness, sensory
panel ratings increased and shear forces values decreased as fat thickness increased; however,
differences as fat thickness increased from 5 and 13 mm were not statistically related to the panel
scores (P > .05). Subcutaneous fat, more than 10 mm, did not decrease the number of steaks
that were rated “undesirable.” These results suggest that fat thickness and beef palatability are
not linear or additive. When comparing beef palatability to the combined effects of fat thickness
and marbling, palatability was increased linearly with marbling but was negligible with fat
thickness. The degree of collinearity between marbling and subcutaneous fat thickness was low
($r^2 = .06$; Tatum et al., 1982). Forty-eight Simmental crossbred steers that were A-maturity and
were slaughtered at specific fat thickness levels of 0.5, 1.0, and 1.5 cm, were correlated with flavor, juiciness, tenderness and overall acceptability (Parrett et al., 1985). Fat thickness was significantly related ($P < 0.05$) with juiciness and overall acceptability but the relationship was weak ($r = 0.12$ and 0.14, respectively). Fat thickness also had a significant relationship ($P < 0.01$) with tenderness but the relationship was weak ($r = 0.16$). Fat thickness was not found to be significantly related ($P > 0.05$) with flavor (Parrett et al., 1985).

In a Texas A&M study, frame size and muscle thickness were observed for their ability to improve palatability. Muscle thickness scores (1 = extremely thickly muscled; 9 = extremely thinly muscled) were based on muscle development in relation to skeletal size (muscle:bone). The palatability attributes (juiciness, myofibrillar tenderness, overall tenderness, flavor desirability, overall palatability) were evaluated by an experienced sensory panel and a majority of the attributes were not significantly related to ($P > 0.05$) muscle thickness levels (Dolezal et al., 1985). Another Texas A & M study, using 101 steers and bulls of mixed breed and unknown history, were fed for 135 d on high concentrate feed (38.8 % flaked corn, 38.8% high-moisture corn, 6.0% alfalfa hay, 12.0% corn silage, and 4.4% liquid supplement) and transported to a commercial packing plant for slaughter and carcass evaluation. A trained, 8-member sensory panel conducted an evaluation of juiciness, muscle fiber tenderness, connective tissue amount, overall tenderness and overall palatability using 8-point descriptive scales. Off-flavor was evaluated on a 4-point descriptive scale (4 = no off flavor, 1 = intense off-flavor). Marbling was related ($P < 0.05$) to sensory panel tenderness score values with a correlation of $r = 0.20$ and $r = 0.27$ for tenderness ratings for steers and bulls, respectively. Subcutaneous fat thickness for bull carcasses was related ($P < 0.05$) to overall tenderness and overall palatability ($r = 0.25$ and $r = 0.32$, respectively). Carcasses categorized based on degree of marbling and fat thickness
demonstrated that those with “slight” or more marbling and 0.76 cm or more fat thickness produced more “acceptable” loin steaks 12.2% points more often than carcasses with less marbling and lower level of fat thickness. A stepwise multiple regression was conducted to establish how much variability was explained in the palatability with the inclusion of different carcass characteristics. These results indicated that an equation for steers including marbling and % KPH accounted for only 12% of the variation in the overall tenderness ratings. An equation for steers including marbling, subcutaneous fat thickness, carcass sex class and % KPH accounted for only 12% of the variation in overall tenderness ratings. The investigators concluded that marbling was more efficient at identifying steer and bull carcasses according to “acceptability” of loin steaks for cooked palatability than subcutaneous fat thickness, sex class, breed-type group, or combinations of carcass traits (Johnson et al., 1988).

Another study by May (1992) examined the interrelationships among days fed, carcass weight, subcutaneous fat, marbling score, and beef palatability. Most sensory panel variables (tenderness, flavor, juiciness and marbling) increased curvilinearly (P < 0.05). The correlation of marbling to tenderness, flavor, and juiciness was 0.51, 0.34, and 0.31, respectively. The correlation of fat thickness to tenderness, flavor, and juiciness was 0.45, 0.30, and 0.15, respectively (May et al., 1992). More recently, a study was conducted at Texas Tech University to determine the interaction of external fat thickness (<0.5 cm or ≥0.5 cm), slaughter plant location (Kansas vs. Texas), quality grade (USDA Low Choice vs. USDA Select), and aging time (7d vs. 14 d) on sensory traits and Warner-Bratzler shear force (WBS) values of beef loin strip steaks. All carcasses in this study underwent electrical stimulation (low voltage = 70 V). The results indicate that fat thickness did not affect means or standard deviations for any of the sensory traits or WBS values (P > 0.3). These data confirm that fat cover is not necessary to
ensure tenderness of aged beef from carcasses receiving electrical simulation (Miller et al., 1997).

1.1.2 Percentage kidney, pelvic, and heart fat

The percentage KPH is the internal carcass fat associated with kidney, pelvic cavity, and heart expressed as a percentage of the chilled carcass weight. The kidney is included in the estimate of kidney fat. The percentage KPH is one of the factors used to determine yield grade (Boggs et al., 2006). As the KPH percentage increases, yield grade increases numerically (toward 5) and the percentage of boneless, closely trimmed retail cuts decreases. The range of percentage KPH values include extreme (0.5 – 6.0%), normal (1.0 – 4.5%), and average (2.0%) for steers weighing 544.3 kg. This factor is estimated in pounds for each side. The two sides are totaled and then divided by the carcass weight to arrive at the percentage (Boggs et al., 2006).

1.1.3 Rib-eye area

Rib-eye area (REA) is the area of the longissimus muscle measured at the 12th rib interface on the beef forequarter (Boggs et al., 2006). Rib-eye area is a fair to good estimator of total carcass muscle, but is widely used because it is measured with accuracy and ease. The rib-eye area is one of the factors used to calculate yield grade. As the REA increases, yield grade decreases in numerical value (toward 1.0) and the percentage of boneless, closely trimmed retail
cuts increases. Rib-eye area is an assessment of muscling, while the other three yield grade factors (adjusted fat thickness, hot carcass weight, percentage kidney pelvic, and heart fat) assess fat. Rib-eye area is measured by a direct grid reading of the eye muscle or a planimeter reading from a tracing of the muscle. The grid reading is faster and used more often than the planimeter (Boggs et al., 2006).

1.1.4 Carcass weight

Carcass weight is recorded as either hot (HCW) or chilled (CCW). HCW is the weight of the carcass after the blood, hide, feet, head, and internal organs have been removed just prior to chilling and CCW is the weight of the carcass after chilling for at least 24 hr (Boggs et al., 2006). HCW generally equals the chilled carcass weight multiplied by 101.5. Weight is easy to obtain, therefore it is the most commonly used characteristic to determine value although, alone, it is not an accurate estimate of the amount of closely trimmed retail cuts that can be obtained from the carcass. HCW is usually obtained in beef slaughter plants, whereas cold carcasses are rarely weighed before fabrication. As HCW increases, the yield grade increases numerically (toward 5.0), but the percentage of boneless, closely trimmed retail cuts decreases. In other words, as weight increases, so does the amount of carcass fat. This observation may change depending on the body size and degree of marbling (Boggs et al., 2006).
1.1.5 Color and texture

Color and texture of the rib-eye muscle can be examined once the maturity group has been established since they are factors in determining quality grade. First, these factors are used to finalize the maturity group that has already been established based on bone and cartilage characteristics. In terms of chronological age, the buttons, located on the dorsal tip of each spinous process of the thoracic vertebrae, will ossify as the cattle approach 30 mo of age. Beef cattle from 9 to 30 mo of age are usually acceptably tender and considered to be the A maturity group. As the animal increases in age, ossification of cartilage increases and generally the tenderness decreases. Older animals are considered the B maturity group, and may qualify for USDA Prime, Choice, and Standard grades. If adequate marbling is present, when the animal reaches 42 mo of age, the ossification of cartilage in the sacral lumbar region already has been established and the buttons in the thoracic region have begun ossifying extensively. Also, by 42 mo of age, the collagenous connective tissue associated with muscle has undergone extensive cross-linking, which increases toughness. These carcasses are considered to be C, D, and E maturity groups, which are generally much tougher than the A and B maturity groups. Cattle over 42 mo are only eligible to be graded as USDA Commercial, Utility, Cutter, and Canner. Since C, D, and E lack tenderness, they are not generally marketed as roasts or steaks, and are sold as ground beef and further processed meat products. Utility includes any grade (C through E) that can not be graded as Standard or Commercial (Boggs et al., 2006). Color of the lean muscle changes from a light grayish-red to a dark red as the animal matures. The texture of the lean muscle becomes coarse in mature animals. From a consumer point of view, the ideal color and texture is bright red and fine, respectively. It is not desirable to have extremely dark or
extremely light color, since extremely dark colors are associated with older animals (Aberle 2001).

1.1.6 Marbling

Marbling is the amount of fat within the muscle (intramuscular fat). It is normally measured in the longissimus muscle at the 12th rib. The range of marbling includes extreme (devoid-abundant), normal (traces-abundant), and average (slight-modest; Boggs et al., 2006). The average range is the amount required to grade Select to average Choice. These marbling terms are used by the Federal Grading Service (Boggs et al., 2006). The level of marbling is related to many factors including genetics, time on high energy feed, and animal health. Marbling is considered the most important factor affecting quality grade and is the most accurate predictor of palatability when compared to other carcass characteristics (Tatum et al., 1982; Dolezal et al., 1985; Johnson et al., 1988; May et al., 1992; Parrett et al., 1985). A study by Platter et al. (2003) was conducted to quantify the impacts of changes in several common beef traits (marbling score, WBS, and consumer panel sensory rating for tenderness, juiciness, or flavor) on the probability of overall consumer acceptability for beef strip loin steaks. This study compared the marbling score of strip loin steaks (n = 550) with the acceptability by consumers (n = 489). The sensory model that was utilized included 3 factors (tenderness, juiciness, and flavor) because of their strong relationship to consumer acceptance ($R^2$ adjusted = 0.62) and more discriminatory power (c-statistic = 0.908) than single consumer sensory rating models (data not provided). Using logistic regression, the investigators were able to quantify and characterize the
effect of marbling on consumer acceptability. They found that marbling score had a weak 
(adjusted $R^2 = 0.053$), yet significant ($P < 0.01$) relationship to the consumer acceptance of these 
steak samples. The shape of the predicted curve for steak acceptance was just about linear over 
the entire range of marbling scores (Traces to Slightly Abundant). This finding implies that the 
likelihood of consumer acceptance of steaks increases about 10% for each full marbling score 
increase between Slight and Slightly Abundant (Platter et al., 2003). Beef grading standards were 
developed originally in 1916 by the USDA in order to separate groups of animals into classes 
and grades with similar characteristics for marbling (Boggs et al., 2006).

It is evident from this research that consumer acceptability is extremely variable even 
after examining carcass traits. Therefore, it is imperative to continue research to ensure the 
accuracy of these predictions.

1.1.7 Yield grade

Yield grade is a numerical value (1 to 5) intended to predict the yield of boneless, closely 
trimmed (about 7.62 mm) retail cuts from the round, loin, rib, and chuck (Boggs et al., 2006). 
These four cuts make up 75% of the weight, but 90% of carcass value. Individually, the round 
makes up 23% of the weight and 29% of the value; the loin 17% of the weight and 29% of the 
value; the rib 9% of the weight and 11% of the value; and the chuck makes up 26% of the 
weight and 21% of the value. Therefore, the brisket, foreshank, plate, flank (thin meat), and 
kidney knob comprise the remaining 25% of the carcass weight, but only 10% of the value. 
Since the round, loin, rib and chuck account for a majority of the carcass weight, the retail yield
is calculated from them rather than the rest of the carcass. These factors are used to calculate the yield grade or the percentage of boneless, closely trimmed, retail cuts (Boggs et al., 2006):

\[
\text{Yield grade} = 2.5 + (2.5 \times \text{adjusted fat thickness, 12}^{\text{th}} \text{ rib, inches}) \\
+ (0.0038 \times \text{hot carcass weight, pounds}) \\
+ (0.2 \times \text{percentage kidney, pelvic and heart fat}) \\
+ (0.32 \times \text{rib-eye area, square inches})
\]

\[
\% \text{ retail cuts} = 51.34 - (5.78 \times \text{adjusted fat thickness, 12}^{\text{th}} \text{ rib, inches}) \\
- (0.0093 \times \text{hot carcass weight, pounds}) \\
- (0.462 \times \text{percentage kidney, pelvic and heart fat}) \\
+ (0.740 \times \text{rib-eye area, square inches})
\]

1.2 Predictability of USDA quality grades

A study by Neely et al. (1998) examined three types of beef steaks from four USDA quality grade levels within four major U.S. cities (Chicago, Houston, Philadelphia, and San Francisco) and compared them to consumer acceptability. The city had a major influence on consumer acceptability when compared to USDA quality grade; tenderness and flavor also were significant and contributed equally to overall liking (Neely et al., 1998). This finding implied that USDA carcass quality grades may not be providing consumers with complete information regarding the palatability of beef. It also demonstrated that consumers in different locations may have diverse concepts of palatability. Research at Ohio State University examined whether altering quality grades improved the effectiveness of distinguishing between palatable and
unpalatable products. Results indicated that muscle color and pH can be used to increase palatability and consistency of beef products (Wulf and Page, 2000). In 2002, the role of USDA quality grades, city, and consumer segment in combination with degree of doneness and cooking method were compared to consumer satisfaction for clod steaks. Results suggested that cooking methods, not quality grades, were a more accurate predictor consumer acceptability (Goodson et al., 2002).

1.3 Consumer taste tests

The success of beef products depends on consumer acceptance (Moskowitz, 1985). A portion of product failure can be attributed to the producer’s lack of understanding about the consumer. Sensory testing is used to understand what the consumer thinks about their product (Resurreccion, 2004). Consumer (or affective) tests are used to measure the personal response of current or potential customers (Meilgaard et al., 2007). Consumer tests should not be confused with trained taste panels, which are used if more specific, organoleptic information is needed about the products. Consumer tests are primarily used by producers of consumer goods and they are an invaluable method to evaluate consumers’ preferences, whether the product is meeting their demand, and what can be done to achieve consumer acceptability (Meilgaard et al., 2007).

According to USDA data, there has been a 22% decrease in per capita beef consumption from 1970 to 2004 (Davis and Lin, 2005). Research is conducted on beef products to measure consumer acceptability for overall liking, juiciness, texture, tenderness and flavor. The
palatability of the product is predicted by these traits and should be a measure of the overall eating experience.

1.3.1 Tenderness

A Texas A & M study determined consumer perceptions of beef top loin steaks of known shear force and evaluated how buying trends were modified by tenderness and variation of these steaks (Boleman et al., 1997). The steaks were placed into one of the following WBS groups: 1) 2.27 to 3.58 kg (Tender) 2) 4.08 to 5.40 kg (Intermediate) 3) 5.90 to 7.21 kg (Tough). Consumers were able to detect the difference between the three tenderness levels (P< 0.05). Consumers gave higher (P< 0.05) juiciness and flavor ratings to the tender steaks as opposed to the tough steaks. Overall satisfaction was higher (P < 0.05) for the tender steaks, as opposed to the tough steaks. A majority of the steaks purchased (94.6%) were from the tender group, followed by the intermediate group (3.6%), and the tough group (1.8%; Boleman et al., 1997).

1.3.2 Marbling

A consumer study of marbling determined that consumers preferred low-marbling (Slight) in Chicago (7.7%) and San Francisco (11.9%) and are willing to pay significantly more (P < 0.01) for their preference ($1.40/0.45 kg and $1.94/0.45 kg in Chicago and San Francisco, respectively; Killinger et al., 2004b). Researchers at Texas Tech University also evaluated the interaction of external fat thickness, slaughter plant location, quality grade and aging time on
consumer acceptability and shear force values. Aging the beef for 14 d removed the location effect. The USDA quality grades segregated the carcasses based on tenderness. Choice steaks were found to be more tender (P < 0.05) than Select steaks (Miller et al., 1997).

1.3.3 Location

An in-home beef study was conducted to examine the consumer rating for top round steaks and their relationship to USDA carcass quality grade (top choice or high select), city (Chicago or Philadelphia), consumer segment, degree of doneness, cooking method, and marination (Behrends et al., 2005). According to this study, consumers in Chicago rated cooked steaks degree of doneness to “medium or less” higher for overall like, tenderness, juiciness, flavor like, and flavor amount than consumers in Philadelphia (P ≤ 0.02). This observation suggests that geographic location can influence marketing tactics. Therefore, those retailers should be aware of this phenomenon when marketing a product. There also may be certain cooking methods appropriate for specific cuts and following these methods should improve consumer acceptability (Behrends et al., 2005).

Another study examined how geographic location and USDA quality grade impact consumer acceptability. In-home meal preparation and preferences for degree of doneness varies between locations and this presents challenges for the beef industry to develop market-specific promotional campaigns and designing consumer research (Lorenzen et al., 1999).
1.4 Factors that determine consumer preference

Recently, Mennecke et al. (2007) conducted a study using an analysis technique known as “conjoint analysis method” to examine the relative utilities of a set of beef steak characteristics. For this analysis, 1,432 US consumers, including undergraduate students at the business college and in the animal science department, were utilized. This study was important because it determined whether the consumer was willing to pay a premium for certain product information. The data demonstrated that region of origin, defined as a producer who is local, reputable, American, Mexican, Australian or Canadian (total = 27.06 out of 99.98) was the most important determinant among all groups of consumers. Specifically, there was a preference for US-produced beef. However, animal feed, including both grain- and grass-fed beef, was found to have little contribution to the consumers’ purchase decision (total = 7.76 out of 99.98). Animal feed was found to rank higher among those who were more knowledgeable about beef. This study implies that it is imperative for the producer to maintain the identity and the flow of information throughout the production value chain in order to preserve value among consumers (Mennecke et al., 2007).

In Chicago and San Francisco (n = 124 per city), Killinger et al. (2004) conducted a study to examine consumer sensory acceptance and value of beef strip steaks differing in marbling level (high = upper 2/3 USDA Choice and low = USDA Select), but similar in WBS values (P = 0.72). Consumers who were the primary grocery shopper, between the ages of 19-59, and willing to consume beef were identified. Consumers rated tenderness similarly for high- and low-marbled samples (P = 0.22) with a standard error of 0.10. Consumers gave high-marbled steaks a superior rating (P < 0.01) for flavor, juiciness, and overall acceptability when compared to low-marbled steaks with a standard error of 0.08, 0.11, and 0.09, respectively. Consumers in
both cities found high-marbled steaks to be more ($P < 0.01$) desirable in flavor and overall acceptability (Killinger et al., 2004a).

Platter et al. (2005) also conducted a study to examine the disparity in consumer purchasing trends and willingness-to-pay values for steaks from an extensive range of marbling score and WBS values. This study was able to achieve a real market by having the consumers use real money and place bids on real products. The consumers in this study ($n = 489$) were bidding on beef strip loin steak ($n = 541$) and the researchers used experimental economic procedures to measure the impact that changes in marbling score and WBS values had on consumer purchasing behavior. The steaks were classified based on quality grade (Select, Low Choice, Premium Choice, and Prime) and WBS values (very tender, $\leq 3.4$ kg; slightly tender, 3.41 to 4.40 kg; slightly tough, 4.41 to 5.40 kg; or very tough, $>5.40$ kg). The percentage of beef customers who refused to purchase steaks was lowest ($P < 0.05$) for the Premium Choice grade, intermediate ($P < 0.05$) for Low Choice steaks, and highest ($P < 0.05$) for the Select grade. Regarding the WBS values, steaks in the very tender category had the lowest ($P < 0.05$) percentage of beef customers who refused to purchase. Steaks in the very tough categories had the highest ($P < 0.05$) percentage of beef customers who refused to purchase. These findings indicate that consumers are able to perceive differences in steaks with different quality grade and WBS values and imply that marbling score and WBS affect the consumer willingness to pay for strip loin steaks (Platter et al., 2005).
1.5 Consumer preference: grass-fed vs. grain-fed

Grass-fed beef has only recently been defined by the USDA, therefore previous definitions had some variability (USDA, 2007). Although the majority of consumers prefer grain-fed beef (64%), there is a small portion of the population that prefers grass-fed beef (19%) and is willing to pay $1.38/0.45 kg more for that product (Sitz et al., 2005). Comparisons between grass-fed beef and grain-fed beef indicated the levels of marbling ($P = 0.82$) and WBS tenderness values ($P = 0.34$) were similar. In Chicago, 59.0% of the consumers preferred domestic grain-fed beef, while 19.7% of the consumers preferred grass-fed beef. In San Francisco, 61.5% of the consumers preferred domestic grain-fed beef, while 16.5% preferred grass-fed beef (Killinger et al., 2004a). Taste panel research for grass-fed beef steaks has demonstrated that the majority of consumers prefer grain-fed. Trained panelists labeled the grass-fed beef as having a “grassy, fishy off-flavor which is tough” (Xiong et al., 1996). Since these studies were done within the US, it follows that consumers were showing a preference for the products to which they were most accustomed. However, there is variability within grass-fed beef and more research is required to reduce variability for consumer acceptability, including flavor, tenderness, juiciness, and texture.

It was suggested that there is significant variability in carcass quality grades and eating quality of grass-fed beef products (Martz, 2000). This study examined the effect pasture-based finishing had on the eating quality of beef utilizing 80 Hereford X Gelbvieh X Angus or $>\frac{3}{4}$ Angus steers. There were four pasture supplement treatments of 0.0, 0.5, 1.0, 1.5% BW daily concentrate supplement and a conventional feedlot treatment to which the steers were randomly assigned. A sensory evaluation found that none of the beef products rated as “disliked” on a 9-
point hedonic scale. However, the grass-fed beef lacked tenderness and juiciness when compared to the grain-fed beef (Martz, 2000).

Another study was conducted to determine consumer acceptance of forage-fed or concentrate-fed beef (Kerth, 2004). When 30 Charolais-Angus crossbred steers reached 340 kg, they were randomly assigned to one of three finishing treatments consisting of ryegrass only for 178 d (RG), ryegrass for 125 d followed by 98 d of a high-concentrate, feedlot type diet (RGC), or a high-concentrate, feedlot type diet for 82 d (CON). The RGC and CON groups were harvested when they reached a fat thickness of 1.0 cm and the RG group was harvested when the amount of forage was inadequate to support animal growth. The demographic makeup of the consumers (n = 153) were evenly distributed across income levels and gender, with almost half (46.6%) being younger than 30 yr and the remainder evenly distributed from 31-80 yr of age. Overall acceptability and price per pound were higher (P < 0.05) for CON steaks, as compared to RG and RGC. A higher (P < 0.05) percentage of consumers preferred CON (63.9%) steaks than RG (22.2%) and RGC (13.9%). However, some consumers were willing to pay $1.17/kg more for the RG beef than the CON. The investigator concluded that a significant market exists for forage-fed beef and consumers are willing to pay a premium for it (Kerth, 2004).

1.6 Quality traits compared with consumer acceptability of grass- and concentrate-finished beef

A multi-year, multi-institution study was conducted to examine the interaction among stocker nutrition and management, finishing performance, carcass traits, and consumer acceptability (Neel et al., 2007). Angus cross-bred steer calves (n = 216) were randomly assigned to one of three winter-stocker growth rate treatments. Winter (December to April) diets
were formulated to achieve average daily gains (ADG) of 0.23 (low), 0.45 (medium), or 0.68 (high) kg⁻¹⋅d⁻¹. The winter stocker diets consisted of timothy hay, soybean meal, soybean hull, and 6:1 mineral supplement. Following the winter phase, the steers were randomly assigned within each stocker treatment to a corn silage-concentrate or pasture finished system. Steers were finished on equal-time endpoint to eliminate confounding treatment with animal age or seasonal factors. The winter stocker phase treatments led to differences (P < 0.001) in final body weight (BW), average daily gain (ADG), and ultrasound longissimus muscle (LM) area between all treatments for that phase. Pasture-finished cattle had lower (P < 0.001) final BW, ADG, HCW, LM area, fat thickness, percentage KPH, dressing percent, USDA yield grade, and USDA quality grade. The low and medium winter stock treatments were less (P < 0.05) than the high for final BW and HCW. Dressing percent was greater (P < 0.05) for high than low. USDA quality grade was greater (P < 0.05) for high than low and medium. There was no influence (P > 0.05) by winter rate of gain on carcass LM area, fat thickness, percentage KPH, and USDA quality grade. The cattle on the low winter rate of gain achieved a higher rate of gain during the finishing period but were not able to reach the BW or HCW of the high group. The researchers concluded that these data imply the winter stocker period effects finishing performance, carcass quality, and beef production in both pasture- and feedlot-finishing systems, when cattle finished at an equal-time endpoint (Neel et al., 2007).

Duckett et al. (2007) used the cattle from Neel et al. (2007) to study the changes in beef 9-10-11th rib composition, color, and palatability. The steaks were examined for rib composition (fat analysis), Hunter color values (L*a*b*), WBS, 8-member trained taste panel, and collagen content. HCW and the 9-10-11th rib section weight was higher (P = 0.01) for the high than low or medium winter stocker growth rate, but did not effect the 9-10-11th rib composition. The
percentage of fat-free lean was higher ($P = 0.001$) for pasture than from concentrate diets. Total fat percentage of the 9-10-11th rib was 42% lower ($P = 0.001$) for pasture than concentrate diets. The LM color of the pasture-fed beef was darker ($P = 0.0001$) and less red ($P = 0.002$) than concentrate-fed. Juiciness scores were greater ($P = 0.02$) for concentrate-fed compared to pasture-fed beef. There was no difference in initial and overall tenderness scores ($P \geq 0.49$) and WBS values ($P \geq 0.28$). Beef flavor intensity was lower ($P = 0.0001$) and off-flavor intensity was greater ($P = 0.0001$) for pasture than for concentrate diets. Based on these data, the authors concluded that growth rate during the winter stocker period did not influence rib composition, color, or beef palatability. In addition, cattle finished on forage had lower carcass weights and fat percentages but similar tenderness values when compared with the concentrate-finished cattle (Duckett et al., 2007).

1.7 Trends in the beef industry

The United States (US) population is aging; therefore, consumers will have more money and will spend it on healthier foods (Blisard, 2002). An increased amount of health information has influenced the consumption pattern of food commodities (Variyam, 2002). From 1995 to 2000 there was a 178% increase in new “all natural food products” and a 57% increase in new organic products (Harris, 2002). The USDA organic standard has increased consumer confidence in organic claims and demands (Harris, 2002). Since 1970, the US per capita consumption of chicken has increased from 18 kg per year to over 36 kg per year, while per capita beef consumption decreased from 38 kg per year to 28.3 kg per year (Davis and Stewart, 2002). Factors that contributed to this change in US
consumer demand for meat and meat products include 1) increased health concerns; 2) change in demographic characteristics; 3) increased demand for more convenience and increased eating away from home; 4) increased demand for more variety; 5) increased demand for more natural products; and 6) change in prices (Davis and Stewart 2002).

According to Haley (2001), the United States Department of Agriculture (USDA) indicated that the US per capita consumption of meat has increased more than 11% since 1970. However, poultry consumption accounts for the majority of the increase (+15 kg), while beef and veal declined by 6.8 kg. Haley speculated the reasons for the decline in beef consumption may be attributed to health concerns, lack of time to prepare, and higher prices for beef (Haley, 2001).

In addition to the increased demand for palatability, consumers are becoming more health conscious. In 1997, the Economic Research Service (ERS) determined that total meat consumption (red meat, poultry, and fish) was 86.2 kg (boneless, trimmed weight equivalent) per person, which was 5.9 kg above the 1970 level. Separately, each American consumed an average of 9.5 kg less red meat (mostly less beef), 14 kg more poultry and 1.4 kg more fish and shellfish when compared to 1970 (Putnam, 1998).

Contrary to the idea that nutrition and health are the most important factors when making food selections, Acker (1979) explained little evidence exists that nutritional aspects are the sole determinant in the food consumption habits of Americans. In fact, he cites a study by Telser of the A.C. Nielson Company (June 1978) that concluded the most important factors in food selection were cost, convenience, food preferences, social pleasure, and work involved in preparation. Telser acknowledged that nutrition and health are among those factors; however, they are not always the most important. Based on these ideas, Acker believed that national
studies, goals, legislation, or warnings have a minor impact on consumption patterns (Acker, 1979)

1.7.1 Fat and cholesterol

Fat and cholesterol, not from the diet, are needed by the human body to function (Duckett and Pavan, 2007). Cholesterol is found naturally within animals and is a precursor for corticosteroids, sex hormones, and vitamin D. However, high levels of cholesterol can lead to a higher risk for heart disease. Cholesterol accumulation may lead to atherosclerosis, a build up of plaque in the arteries that can block the flow of blood to the heart. This build-up reduces the amount of nutrients and oxygen getting to the heart and can lead to a heart attack or stroke (Duckett and Pavan, 2007). The National Cholesterol Education Program (NCEP) recommends that the maximum total amount of cholesterol should be 300 mg/deciliter (NHLBI, 2002). Dietary cholesterol makes up about 25% of the total cholesterol with the remainder produced naturally in the human body. Therefore, altering the intake of dietary cholesterol has little impact on the total blood cholesterol. Based on the U.S. average daily intake of 450 mg and the recommended daily intake of 300 mg, a reduction of 150 mg/d would reduce the amount of blood cholesterol by 2% (i.e. blood cholesterol of 240 mg/dL will result in a 4.8 mg/dL reduction; Duckett and Pavan, 2007).

The type of fat consumed has major effects on the regulation of cholesterol levels in the body. Fat may influence the lipoproteins, which function to carry cholesterol throughout the body. The two major lipoproteins are high-density lipoproteins (HDL) and low-density
lipoproteins (LDL). High-density lipoproteins carry cholesterol from the blood back to the liver. Low-density lipoproteins carry cholesterol from the liver to the rest of the body. If there is too much LDL, the cholesterol can be deposited into the arteries. The NCEP recommends that the LDL levels be less than 100 mg/deciliter and the HDL levels be more than 40 mg/deciliter (Duckett and Pavan, 2007).

1.7.2 Fatty acids

Fatty acids make up simple and complex lipids. There are more than 1,000 fatty acids recognized. However, only a small portion of them are important from a food analysis standpoint. All fatty acids have a hydrocarbon chain with a carboxylic acid (-COOH) terminal. They differ from one another with regards to carbon chain length and in the position and configuration of double bonds (King, 1996). The double bonds allow for the configurational isomerism in either a cis or a trans position. Naturally-occurring fatty acids usually occur in the cis configuration. The carbon chain is extremely variable but the most common are C:16, C:18, C:20, and C:22. The isomerization of fatty acids are formed during hydrogenation (industrial or within the rumen; King, 1996).

1.7.2.1 Polyunsaturated fatty acids

In free fatty acids, one end of the carbon chain is acidic while the other end has a methyl group attached. The methyl end is also called the omega end. Fatty acids become saturated when the carbons are completely saturated with hydrogen and linked with single bonds.
Unsaturated fatty acids will not have hydrogen linked to every carbon and, therefore, can have several double bonds. If there is more than one double bond, it is known as a polyunsaturated fatty acid (PUFA; Medline Plus (Author unknown), 2006).

Polyunsaturated fatty acids can be divided into two categories, $\omega$-6 and $\omega$-3 (Duckett and Pavan, 2007). Omega-3 fats are highly unsaturated, meaning they do not have as many hydrogens and have several double bonds. Omega-3 is named because the first double bond is on the third carbon from the omega end. If the first double is on the sixth carbon from the omega end, it is an $\omega$-6 fatty acid. The most common $\omega$-3 fatty acids are alpha-linolenic acid (ALA), eicosopentaenoic acid (EPA), and docosahexaenoic (DHA). They differ in the length of their carbon chain and the number of double bonds. For instance, ALA is an 18-carbon chain with 3 double bonds. Omega-3 fats have distinct properties and are found uniquely in different foods. They are important for human health because they lead to the production of eicosanoids that have significant impacts on immune response, blood pressure, blood clotting, body temperature, and cell growth (Medline Plus (Author unknown), 2006). In addition, $\omega$-3 fatty acids affect humans by reducing the risk of heart disease, stroke, and cancer (Kris-Etherton et al., 2002). The average American diets have changed from an equal distribution of $\omega$-6: $\omega$-3 (0.1-2.8) during the hunter/gatherer era to a distribution of 3.3-16.7 in the industrial era (Heller et al., 2005). Since $\omega$-6 and $\omega$-3 fatty acids compete with one another to be converted to the active metabolites in the body, it would be beneficial to either decrease the intake of $\omega$-6 fats, or increase $\omega$-3 fats. (Medline Plus (Author unknown), 2006)
1.7.3 Conjugated linoleic acid

Conjugated linoleic acid (CLA) is made up of positional and geometric dienoic isomers of linoleic acid that are found naturally in foods. CLA is found in many animal products, particularly ruminant sources (Chin et al., 1992). This polyunsaturated conjugated fatty acid occurs naturally as a result of the microbial isomerization of dietary linoleic acid (Chin et al., 1994). CLA was initially discovered to be antimutagenic within cooked beef (Pariza et al., 1979). In 1987, Ha et al. demonstrated that a synthetic form of CLA was anticarcinogenic in mouse skin. They used fried ground beef and produced a highly purified fraction of CLA with high performance liquid chromatography (HPLC). Seven days, 3 days and 5 minutes prior to 7,12-dimethylbenz[a]anthracene (DMBA) application, CLA was applied at doses of 20, 20, and 10 mg, respectively. A control was treated similarly with linoleic acid or solvent (acetone). After conducting a chi-squared ($\chi^2$) test, the investigators found the CLA-treated mice to be significantly different regarding tumors ($P < 0.01$) and tumor incidence ($P < 0.05$) compared to the control mice at week 16 (Ha et al., 1987). Whigman et al. (2000) have described how CLA promotes immune stimulations, anticarcinogenesis, and antiatherogenic effects.

Recently, research has been conducted on specific isomers and their impacts. Ip et al. (1999) examined whether high CLA butter fat (80-90% cis-9, trans-11) has similar biological activities as a mixture of free fatty acid CLA isomers. Butter was made from milk of Holstein cows and was either control or high CLA (5.3% sunflower oil). The animal models were pathogen-free female Sprague-Dawley rats and were divided equally into four treatments: 1) control butter fat; 2) high CLA butter fat; 3) Matreya CLA (mixture); and 4) Nu-Check (synthetic). Results demonstrated that high CLA butter intake (80-90% cis-9 trans-11) during pubescent mammary gland development reduced mammary gland development, reduced
mammary epithelial mass by 22%, decreased the size of the terminal end bud (TEB) population by 30%, suppressed the proliferation of TEB cells by 30%, and inhibited mammary tumor yield by 53% (P < 0.05; Ip et al., 1999). Another study compared the effects of pure trans-10 cis-12 and cis-9 trans-11 on milk fat synthesis (Baumgard et al., 2000). Three lactating multiparous Holstein cows were randomly assigned in a latin square design to the following treatments (via abomasal infusion): 1) skim milk (control); 2) cis-9 trans-11 CLA supplement; and 3) trans-10 cis-12 CLA supplement. The results demonstrated that trans-10 cis-12 supplement significantly (P = .001) reduced milk fat percentage when compared to cis-9 trans-11 and the control (Baumgard et al., 2000). A subsequent study demonstrated that milk fat synthesis was further reduced by 25, 33, and 50% when cows received 3.5, 7.0, and 14.0 g/d of trans-10 cis-12, respectively (Baumgard et al., 2001). Contrary to the belief that only the cis-9 trans-11 isomer will decrease incidence of tumors, Lee et al. (2006) found that the trans-10 cis-12 CLA induced apoptosis in human colorectal cells. To investigate the effects of CLAs (trans-10 cis-12, cis-9 trans-11, LA, or vehicle) on the growth of colorectal cancer (CRC) cells in culture, HCT-116 cells were incubated with 50 μM of LA, cis-9 trans-11-CLA or trans-10 cis-12-CLA for several days and cell proliferation and apoptosis was measured with a Cell Proliferation Assay Kit (Promega) and flow cytometry, respectively. Trans-10 cis-12 CLA reduced cell growth by 40% which was significantly (P < 0.001) more than the vehicle treated cells. There was a 2-fold increase (P < 0.01) of apoptotic cells treated with trans-10 cis-12 CLA, compared to the vehicle-treated cells (Lee et al., 2006).

Since there has been significant CLA research in both animal and in vitro studies, there is now an increased interest in the impact CLA may have on humans. Blankson et al. (2000) explored the favorable effects of CLA on overweight or obese humans in relation to body fat
mass (BFM), lean body mass (LBM), weight reductions, and blood lipids. The subjects in this study were > 18 y old and had a body mass index (BMI) of > 25 kg/m^2 and < 35 kg/m^2. Sixty subjects (men or women) were randomly assigned to two treatment groups in the ratios of 1/3 (n = 20) and 2/3 (n = 40), respectively and within treatments randomized to placebo (9 g olive oil) or 1.7, 3.4, 5.1, or 6.8 g CLA/d. Each dosage was taken at breakfast, lunch and dinner, daily for 12 wk. The active capsules consisted of 750 mg oil of which 75% was CLA. The CLA preparation consisted of equal parts of the \textit{cis}-9, \textit{trans}-10, \textit{cis}-12 isomer. Of the 60 subjects, 47 completed the study. The researcher used repeated measure analysis to demonstrate a significantly higher reduction in BFM in the CLA group than the placebo group (P = 0.03). The reduction of body fat within the groups was significant for the 3.4 and 6.8 groups (P = 0.05 and P = 0.02, respectively). These data suggest that a dose of 3.4 g CLA/d for 12 wk seems to reduce BFM significantly in overweight and obese humans and that no additional effect on BFM is attained with doses > 3.4 g CLA/d (Blankson et al., 2000).

Another study was conducted to determine the effects of moderate doses of CLA on body fat, biochemical parameters of serum related to findings in animal studies, and CLA content of individual serum lipid classes. Unlike the previous study, the subjects of this study were not obese (BMI < 30 kg m^{-2}). The subjects consisted of 14 men and women, aged 19-24, not suffering from any chronic illness, and were not taking any medication or dietary supplements. Each subject was given a balanced isoenergetic weekly dietary plan (based on estimated basal metabolic rate and physical activity) and was asked to record their dietary intake and the quantity of experimental capsules taken daily, as well as any medication they needed to take. Also, they were asked not to change their normal way of life (i.e. physical activity) in any way. The subjects were divided into a study and control group. Each group consisted of seven males and
five females. The study group was given a 500-mg soft gelatin capsule of CLA-70. The researchers confirmed that the capsule contained 350 mg of CLA (69%) with equal amounts of cis, trans-9,11 (49%) and trans,cis-10,12 (51%) isomers by gas chromatographic analysis. The study group was advised to take two capsules (0.7 g CLA) daily for 4 weeks and four capsules (1.4 g CLA) daily for the next 4 weeks. The control group received the same dosage of identical looking capsules containing soybean oil as placebo. The subjects were measured three times (before starting to receive the capsules, immediately after the end of the low dosage, and immediately after the end of the high dosage) and at each meeting, body weight, stature, and thickness of ten skin folds for the estimation of percentage body fat were taken. The authors found a statistically significant (P < 0.001) decrease in the sum of the thickness of ten skinfolds, and, at the same time, percentage body fat and fat mass of healthy humans during the high CLA intake period. Also, patients exhibited a significant (P = 0.001) decrease in the levels of HDL-cholesterol during low CLA intake (Mougios et al., 2001).

In 2000, Zambell et al. conducted a study to examine the impact of 3 g/d/person CLA supplementation on body composition and energy expenditure in healthy women. Although this amount is threefold higher than the expected daily intake for American adults (1 g/person/d as reported by Ha et al.(1987), the authors stated the concentration was still within the reasonable range for a healthy, non-vegan adult. The study consisted of seventeen women, aged 20-41 yr. To ensure healthiness, the selection criteria included being a healthy nonsmoker, premenopausal with normal menstrual cycles, and free of any abnormal physiological conditions or diseases. For the entire duration of the study (94 d), subjects lived in a metabolic suite, where meals and daily activities (daily outdoor walk: 4.6 km/d) were standardized. The subjects were divided into two cohorts (9 in the first cohort and 8 in the second). The cohorts each lasted 94 d with a 30 d
baseline and then a 64 d intervention period where they were given either CLA or placebo capsules. During the baseline period, all subjects were administered a daily placebo capsule containing sunflower oil to become accustomed to taking capsules. On day 31, 10 participants were randomly assigned to get supplemental CLA for the remainder of the study (~3 g/d). The CLA made up about 65% of the total fatty acids in the capsules, with the remainder consisting primarily of oleic acid. Gas chromatography determined that the isomer composition of the CLA was 22.6% trans-10,cis-12; 23.6% cis-11,trans-13; 17.6% cis-9,trans-11; 16.6% trans-8,cis-10; 7.7% trans-9,trans-11 and trans-10,trans-12; 11.9% other isomers. The placebo capsule consisted of 72.6% linoleic acid with the remainder being palmitic, stearic, and oleic acids and no detectable CLA isomers. Body weight was taken every morning and body composition was taken 3 times/week. Energy expenditure was measured once during the baseline and twice during the intervention period (weeks 4 and 8). The researchers reported that CLA did not have significant (P > 0.05) effects on weight (kg; P = 0.35), fat free mass (kg; P = 0.88), fat mass (kg; P= 0.82), and body fat (%; P = 0.39). The CLA mixture did not have a significant effect (P > 0.05) on fat oxidation during rest/walking or on energy expenditure in adult women (Zambell et al., 2000).

1.8 Fatty acids in grass-fed beef

Monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) were found to be antithrombogenic, and ruminants are normally higher in SFA and lower in the PUFA:SFA ratio when compared to nonruminants, French et al. (2000) conducted a study to
examine whether a grass-based diet can increase the PUFA:SFA ratio in ruminant fat. The diets provided in this study were: 1) grass silage for *ad libitum* intake plus 4 kg of concentrate; 2) 8 kg of concentrate plus 1 kg of hay; 3) 6 kg of grazed grass DM plus 5 kg of concentrate; 4) 12 kg of grazed grass DM plus 2.5 kg of concentrate; and 5) 22 kg of grazed grass DM. The authors found that cattle fed diet 5 had significantly higher (P < 0.05) PUFA in intramuscular fat than any other ration. These data also indicated that including grass in the diet of crossbred steers can improve intramuscular fatty acid composition from a human health standpoint (French et al., 2000).

In 1993, Duckett et al. studied the effect of time on feed (TOF) on the nutrient composition of beef. Forty-six Angus x Hereford steers were divided equally into eight groups. The groups were based on days on high-concentrate diet (87.5% DM, 1.84 Mcal/kg of NE<sub>m</sub>, 1.19 Mcal/kg of NE<sub>g</sub>) except for d-0, which was assigned grass-fed control. Groups were then serially harvested at 28-day intervals (0 to 196 d). The intra-muscular fat doubled between 84 d to 196 d (P < 0.05), but was not significantly different from 0 d to 84 d (P > 0.05). The PUFA concentration in the polar lipids decreased linearly (P < 0.05) across the TOF. As the time on high-concentrate feed increased, MUFA increased by 22% and the PUFA decreased by 72% in the longissimus muscle. The ratio of hypercholesterolemic (C14 + C16):hypocholesterolemic (MUFA:PUFA) fatty acids was lower (P < 0.05) for the grass-fed cattle (d 0) than for the d 28 to d 84 and d 196. Cholesterol content (milligrams/100 grams) was changed cubically (P = 0.06) with increased time on feed (Duckett et al., 1993).

Another study examined the effect of duration of grazing (predominately perennial ryegrass) before slaughter on fatty acid composition of muscle fat and subcutaneous adipose tissue of pasture-fed beef heifers. Sixty crossbred Charolais heifers (n = 15 per treatment) were
randomly assigned to one of four treatments. Treatments 1, 2, and 3 were housed at the beginning of the experiment and treatment 4 was fed pasture. Treatments 2 and 3 were moved to the pasture at 40 d and 99 d, before slaughter, respectively. Grazing periods were 0, 40, 99, or 158 for treatments 1, 2, 3, and 4, respectively. Increased duration of grazing led to a linear increase (P < 0.001) in the concentration (on fresh-tissue basis) of CLA in muscle fat. Concentrations were 11.80 to 17.75 mg/100 g of muscle in neutral lipid, from 0.52 to 0.82 mg/100 g of muscle in polar lipid and from 3.98 to 10.23 mg/g in subcutaneous adipose tissue (SAT; P < 0.001). There was an increase in C18:1, trans-11 in both polar and neutral muscle fractions and SAT (P < 0.001). An increase in the ratio of polyunsaturated to saturated fatty acids (PFA:SFA), from 0.12 to 0.15 with an increased duration of grazing following a linear (P < 0.05) and cubic pattern (P < 0.05) was observed. Increasing grazing time led to a linear decrease in the ω-6: ω-3 ratio of muscle fat from 2.00 to 1.32 (P < 0.001) and from 2.64 to 1.65 in the SAT lipids (P < 0.001). The investigation concluded that muscle fat and SAT fatty acid profile were enhanced from a human health standpoint by pasture feeding and that the fatty acid profile improved with increased duration (Noci et al., 2005).

Although these data have demonstrated that grass-fed beef has a significantly different fatty acid composition from grain fed beef, which may lead to improved consumer health, there have been significant problems with respect to variability within the grass-fed product. According to Griebenow (1997), excluding grain from the cattle diet will lead to an increase in dieterpenoids, specifically Phyt-2-ene which may be related to inconsistent grades and grassy flavors in the final beef product. The diterpenoids are derived from the action of ruminal microbes as they break down chlorophyll found in plant-based diets (Griebenow, 1997).
1.8.1 CLA in Grass-fed Steaks: A Human Perspective

Based on data from Sonan et al. (2005), which included data from the Appalachian Pasture Beef Systems Project, the conjugated linoleic acid content in grass-fed ribeye steaks from 200 Angus cross steers was 2 mg/85.2 g serving (Sonon et al., 2005). Referring to Blankson et al (2000), the authors believed that 3.4 g CLA/d may lead to beneficial effects. The deficiency in the literature related to CLA effects on human health is demonstrated by the differences in intake of CLA in the Sonan et al. and the Blankson et al. papers. An equivalent intake of CLA would be over 30,000 g of meat per day to reach the level of intake reported by Blankson, et al. There are no data currently in the literature to support human health effects for the level of CLA intake from grass-fed meat.

1.9 Economic benchmarking for grass-fed beef production

A search of U.S. agricultural journals demonstrates that there are no studies determining the economic benchmarks for grass-fed beef in the United States. However, there are a few observational and testimonial studies that grass-fed beef producers and researchers have compiled. Williams (2007) cited a survey indicating 63% of the consumers surveyed would buy more natural/organic meat if the product was lower in price. The priority areas of improvement for the meat department were reported as quality and increased variety, as well as better pricing, more sales, better quality without deception, and smaller portions. The survey prediction for future beef demand was there will be a strong demand for consistent, high quality beef within the hotel and restaurant market, in addition to the retail market. Williams argued that efficiency can
impact overall profitability and spreading of fixed costs of production. His data were based on a grass-fed cow/calf operation, with a mean heard size of 87 calves weaned, that reflected a cow with a mature weight of 680.4 kg, 258.6 kg of progeny retail yield, a retail value of $2,298.95, and a total retail value (calf crop) of $119,545.40. The data Williams reports from a mature cow with a weight of 453.6 kg with 87 calves weaned, 180.98 kg of retail yield, a retail value of $1,608.91, and a total retail value (calf crop) of $139,975.17. The mean calf breakeven was $1.40/kg (Min = $0.80/kg Max = 1.89/kg; Williams, 2007).

According to an observational report conducted by Matt Cravey (2007), the costs associated with growing and finishing grass-fed beef include the animal cost (~$500-750), average daily gain (~0.675-0.90 kg/d), days to finish (275-500), and financing or carrying cost at 8.25-9%. Additional costs come from source of verification (tags: $1-3.5/hd), ultrasound ($6-10/hd), and pasture costs (seed, fencing, fertilizer, etc.:$74.07 to 283.95/hectare), management and labor, custom grazing option, supplement ($0.11- 0.31/kg), health and prevention (program protocols, vaccination, modified live versus killed, costs of outs from antibiotic treatment: $2-45/hd), freight ($1.55-2.02/loaded km), animal handling (dark cutters, shrink, bruising-trim loss), and water and feed. He also obtained the cost of grain for different levels of maturity assuming the producers are providing pasture + supplement. The overall average cost of gain was reported as $0.89-1.78/ kg. The author stated that grass-fed beef producers are paid on finished weight, providing a range of 499.0 to 589.7 kg. A summary was provided that included total cost per carcass (Mean = $1,133 Min = 909 Max = 1,397 (Cravey, 2007).

A 2006 study conducted by Acevedo et al. compared the profitability of organic, natural, and grass-fed beef. For the purposes of the current study, only the grass-fed analysis will be mentioned. They formulated a cost analysis for grass-fed beef using simulated numbers based
on the estimated recommended small frame size, and assumed a lower cost/head than grain-fed cattle. The daily gain of growing animals was estimated using the Cornell Net Carbohydrate and Protein System model (CNCPS) and the seasonal variability of grass. Therefore, the simulated organic grass-fed cost of calf production was $0.65/kg and the natural grass-fed cost of calf production was $0.60/kg. They made the assumption that the calves were weaned November 1 and used the temperatures for Ames, Iowa from 1951-2005 from the Iowa Environment Mesonet for the simulation. The grass-fed systems wean the calves on winter grazing with supplemental hay when needed plus a vitamin-mineral supplement. The estimated feed intake was simulated based on the assumption that they use only pasture, hay, salt, and trace mineral supplement, but no corn or corn silage. The estimated supplement feed intake for organic grass-fed and natural grass-fed was 12 kg for both. The estimated production performance for the grass-fed systems was simulated based on the assumption that the grass-fed system has a lower percentage of animals grading Choice compared to grain fed. Also, because cattle have leaner carcasses with less external fat, they have a lower dressing percentage. The dressing percentage and the carcass weight for the two grass-fed systems was 61% and 282.6 kg, respectively. They calculated a budget analysis that was divided into variable costs, fixed costs, and income for each system. The budget analysis summary for the two grass-fed systems were similar, but the selling prices and profits are higher for organic (as defined by USDA; $0.99/kg and $-10/hd, respectively) than natural (as defined by no growth promotants or subtherapeutic antibiotic intake; $0.88/kg and $-173/hd, respectively). The authors believed this was discrepancy due to the natural producers having less weight to sell, but selling it at a lower price (Acevedo et al., 2006).
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Chapter 2

The Relationship of Animal, Production, and Carcass Traits with the Consumer Acceptability of Grass-Finished Steaks

2.1 ABSTRACT

Twenty grass-finished steers and 10 grass-finished heifers were evaluated for the relationship of daily BW gain, sex, grazing period, frame size (Beef Improvement Federation, 2002), final weight, and carcass traits (fat thickness, ribeye area, marbling score, and yield grade). Consumers also evaluated tenderness, juiciness, flavor, texture, and acceptability of cooked steaks from these animals. All of the cattle were wintered for a targeted weight gain of 0.73 kg/d for 156 d postweaning and then were maintained in rotationally-grazed paddocks containing primarily cool-season grasses. Cattle were harvested at a constant age (532.9 d ± 5.7 d) in 6 harvest groups ranging from 124 d to 187 d of grazing and carcass data were collected.

Six longissimus muscle steaks were taken from each of the thirty carcasses and consistently labeled for position on the 9th to 12th rib section of the longissimus muscle. One of the steaks from each of the carcasses was evaluated for tenderness using the Warner Bratzler shear force test.

A steak from each of the thirty carcasses was thawed, cooked and offered to consumer panelists. Correlations were determined on the relationship of animal, production, and carcass traits with the consumer evaluations. Results indicated animal factors, growth rate, and carcass traits were not strongly related to panelist evaluations of tenderness, flavor, juiciness, meat
texture, or overall desirability for grass-finished cattle harvested at 533 d of age. Average panel scores for grass-finished steaks were moderate for overall liking, flavor, and juiciness, while scoring them slightly tough. Significant variation in scores for tenderness, texture, flavor, and overall desirability were found, indicating post-harvest interventions may be more effective in increasing consistency for consumers of grass-finished meat compared to using production and carcass traits. This information would be useful to producers who are researching ways to improve consumer acceptability and it demonstrates how production and carcass traits may not be good predictors of consumer acceptability of these grass-finished steaks.

(Key words: Grass-finished, beef, consumer)
2.2 INTRODUCTION

Grass-fed beef (GFB) has been receiving a great deal of attention among health-conscious consumers. This attention can be partially attributed to data reflecting GFB had significantly higher concentrations of conjugated linoleic acids (CLA) when compared to grain-fed beef (French et al., 2000), and documented in studies with rats influencing immune response, being anticarcinogenic, and being antiatherogenic (Baumgard et al., 2000; Ip et al., 1999; Lee et al., 2006; Whigman et al., 2000). In addition, fatty acid profiles are improved and there is less saturated fat in the product (Duckett and Pavan, 2007).

One of the major obstacles for increasing market share for GFB is consumer acceptability. Grass-fed beef has been documented by trained panelists as having a strong (P ≤ 0.05) “grassy” flavor two days post-mortem and developing more (P ≤ 0.05) of an off-flavor after 10 days of aging compared to grain-fed beef (Xiong et al., 1996). Consumers also gave grain-fed beef higher (P < 0.001) scores for flavor, juiciness, tenderness, and overall acceptability when compared to grass-fed beef (Sitz et al., 2005). Although this research has documented differences between grass- and grain-fed beef, there is little data focusing only on grass-fed beef. There is a niche group of consumers who prefer grass-fed beef. The report from Fuez and Umberger (2001) illustrated that 23% of American consumers preferred the taste of grass-fed beef and were willing to pay an average of $3.00/kg more for this choice. Kerth et al. (2004) found that 22.2% of consumers preferred grass-fed steak compared to meat from cattle fed high concentrate diets, and they were willing to pay $1.17/kg more for this product. A report from Martz (2000) indicated that grass-fed steaks lacked tenderness and juiciness compared to grain-fed steaks; however, none of the steaks were rated as ‘disliked’ on a 9-point hedonic scale. These data support the notion that there is a demand for grass-fed beef and consumers are willing
to pay a higher price for it. Therefore, in order to compete in the market of health-conscious consumers, it is imperative that research be conducted to reduce variability and improve the quality of grass-fed beef.

There are no known data relating production and carcass traits with consumer evaluations of only GFB. There is a need for research comparing carcass traits to consumer tests to determine if these traits influence consumer acceptability. The objective of the current study was to determine whether there is a relationship between production and carcass traits of grass-finished cattle with the palatability of the meat.
2.3 MATERIAL AND METHODS

2.3.1 Background

An experiment was conducted with the consent of the Pennsylvania State University Institutional Animal Care and Use Committee (IACUC #20625). A consumer taste test was conducted with the consent of the panelists (IRB # 24404). The experiment consisted of 20 grass-finished steers and 10 grass-finished heifers. All of the cattle were wintered together postweaning for a targeted weight gain of 0.73 kg/d for 156 d. The cattle were progeny of Angus/Simmental crossbred cows that ranged from 25% to 88% Angus, and all cattle were sired by Angus bulls both AI and naturally with 9 sires represented.

2.3.2 Animal feeding and management

Prior to weaning, the cows and their calves were housed on the Haller Farm at The Pennsylvania State University. The daily procedure consisted of checking the water every morning and supplying mineral supplements if needed. The minerals (Young’s Brood Cow, Minneapolis, MN) were available ad libitum. The cows and calves had access to grass/legume pasture consisting primarily of cool season grasses. The test cattle received no grain prior to weaning at an average age of 188 d. The weaning dates were September 19, 2005, October 10, 2005, October 26, 2005, and November 2, 2005. The animals were then wintered at the Beef and Sheep Center at The Pennsylvania State University.
The twenty steers and ten heifers were housed at the Beef/Sheep Center beginning on November 22, 2005. There were no subtherapeutic levels of antibiotics provided. Four animals were treated for foot rot with an injectable antibiotic LA200 (Liquamycin; Pfizer, Exton, PA). The cattle were maintained in a 5.3 hectare pasture, which was wooded on 3 sides for protection and contained rolling hills with depressions for shelter. The cattle had *ad libitum* access to round grass bales (predominantly orchardgrass) and were fed whole shelled corn at 3.0 kg/head/d from November 22, 2005 to January 27, 2006. Between January 27, 2006 and April 26, 2006 the amount of corn was increased to 4.0 kg/head/d. Grain was added to the diet to achieve a targeted average daily BW gain of 0.73 kg/d. The actual average daily BW gain was 0.69 ± 0.03 kg/day for the 156-d wintering period. The pastures were primarily cool-season grasses such as tall fescue, legumes, and weeds, with orchardgrass as the dominant species. There were a total of six feed bunks that were 2.44 meters long (0.3 meter of bunk space/calf). The cattle were fed round grass bales *ad libitum* in Hay Savr® (J&L Equipment, Stoystown, PA) elevated cone feeders. All cattle had *ad libitum* access to water and minerals in a mix containing 8% calcium, 24% phosphorus, and 68% salt (Young’s inc. Roaring Springs, Pa). The cattle resided at the Beef-Sheep Center until April 26, 2006.

Cattle were transported for 2 km from the Beef and Sheep Center pastures on April 27, 2006 to the Penn State Haller Farm. The fertilization process consisted of urea nitrogen (46 % nitrogen; Helena Chemical, Warrriors Mark, PA) applied three times. The first application was March 31 at a rate of 48 kg N/ha. The second application was May 25 at a rate of 30 kg N/ha. The third application was August 31 at a rate of 20 kg N/ha. Twenty steers and 10 heifers remained on Haller Farm pastures until each group was harvested. Twenty-eight additional yearling heifers (not a part of study) were rotated through the paddocks during the first rotation.
(May 5-18). These additional animals acted as defoliators to remove excess growth and to allow for good quality forage for the research groups. The subsequent rotations only included the animals pertaining to the current study. Twenty steers were grazed in one group and 10 heifers grazed in the other group. Each group was rotated through 8 different paddocks, achieving a total of 16 paddocks for the study. Each paddock was approximately 0.19 hectare/heifer and 0.37 hectare/steer. They were moved typically twice weekly. Paddock sizes were variable with entry in the paddock typically 30 cm of forage height and removal at 10 cm of forage height. No supplemental feeds were used as forage was continuously available.

All cattle were weighed at turnout after a 16 hr shrink and frame scores were determined. Grazing paddocks were grass-legume pastures containing primarily cool-season grasses (Table 2.1). Pasture collection was conducted on September 26, 2006 at Haller Farm where the cattle grazed within the Pennsylvania State University. A metal grid was thrown to a random spot of the paddock. A hand-held grass cutter was used to cut ¾ of the grass in the grid. This process was conducted five more times in random spots along a straight path. After the collection, all the samples were put into a cooler. Half of the pasture was put into a paper bag (not separated). The pasture was first separated into orchardgrass, legumes, tall fescue, and weeds or dead grasses.

All the cattle were allotted to the paddocks on the same date. Paddocks were sampled by randomly casting a 1 m² frame 3 cm tall in the paddock prior to each rotation. The samples were collected approximately once a week from May 2, 2006 until October 24, 2006, dried at 55°C for 48 hours, and ground through a 1mm screen and frozen. At a later date, samples were thawed and evaluated at the Cumberland Valley Analytical Services, Inc. for protein (CP; AOAC, 1990) and subjected to near-infrared reflectance (NIR) analysis, using a prediction equation constructed in-house by wet chemistry (New Cumberland Valley Analytical Services, Inc. Maugansville,
The information reported from the laboratory was on crude protein (% dry matter), total digestible nitrogen (TDN, % dry matter), and neutral detergent fiber (% dry matter). Protein, fiber, and TDN values of the pastures for the entire grazing period are shown in Figures 2.1 to 2.3.

Cattle had continuous access to water and minerals (Young’s Brood Cow, Minneapolis, MN) during the grazing period. Grazing continued at Haller Farm until October 30, 2006 when the final harvest group was removed. Standing forage mass was available for the entire grazing period to allow for optimum intake.

2.3.3 Cattle harvest

Five cattle were harvested at a constant age (532.9 d ± 5.7 d) in each of 6 harvest groups. The oldest harvest group spent 124 d grazing and the youngest harvest group spent 187 d grazing. All cattle were harvested at a single facility (N. S. Troutman and Sons, Freeburg, PA) after a 2 hr haul. Fat thickness, marbling score, percentage KPH, final weight, and ribeye area were collected after a 24-hr chill. All marbling scoring was done by a single trained grader. Following data collection, the 9-12 section of longissimus muscle was removed from the left side of the carcass, freezer wrapped, and transported to the Pennsylvania State University Meats Laboratory. Six steaks, 0.6 cm thick, were removed, and labeled based on position on the carcass, vacuum packaged (Bizerba, Piscataway, NJ) within 1 hour in a 3 mm thick vacuum package, and frozen in -4°C freezer for a maximum of 144 d for the shear force test, 68 d for the consumer test and 302 d for the fatty acid and cholesterol analysis.
2.3.4 Laboratory analysis

2.3.4.1 Shear force test

The shear test was conducted at the Meats Laboratory of Pennsylvania State University. Before the test began, 30 steaks were thawed for 24 hr in a refrigerator (2-3°C) within their vacuum package. The oven (General Electric, Model # JBP26W4WH; Louisville, KY) was preheated to 176.7°C. Six random steaks were unwrapped, fat and connective tissue was trimmed, and a pre-cooked weight was taken. Each steak was wrapped in aluminum foil on a metal tray with steaks arranged in two columns and three rows. The tray was put in the preheated oven for 20 min. After 20 min the steaks were probed with a thermocouple (Model HT680A, Cooper Instrument Corp., Middlefield, CT). Each steak was removed once it reached the lowest internal temperature of 70°C. After all the steaks were removed from the oven they were cooled at 22°C for 15 min, blotted to remove excess fluid, and weighed to determine cook loss. The steaks were then cooled at 22°C for an additional 1 hr. Steaks were cored (1.27 cm cores), with 3 cores per steak parallel to the cut surface and sheared (Model TMS-90 Texture Test System, Food Technology Corporation, Rockville, MD.). Peak shear force was recorded as kg of force, using a Warner Bratzler type shear cell (Model CW-1). This entire process was repeated until all 30 steaks were assigned shear force values. Shear force values were recorded as the average force over the three samples from each steak.
2.3.4.2 Consumer test

The consumer test was conducted at the Department of Food Science Sensory Laboratory of Pennsylvania State University (IRB #24404). Four frozen steaks were randomly chosen and removed from the vacuum packaging. The steaks were thawed overnight in a 2-3°C refrigerator. Two steaks were grilled on each of the two George Foreman Next Generation Grills (Model # GRP99). The grills were set to 162.7°C and each steak was cooked to an internal temperature of 60°C measured with a thermocouple (Model HT680A, Cooper Instrument Corp., Middlefield, CT). Each steak was then cut into approximately seven, 0.6 cm² pieces. The order of presentation was randomized and the samples were coded with randomized 3-digit codes. Samples were served to consumers less than 5 minutes after cooking and were kept warm on hot plates. Three 0.6 cm² samples were served to 7 consumers every 30 min. This entire process was repeated for each group of randomly chosen 4 steaks. This process resulted in each steak being sampled by 7 panelists. Standard sensory test methodology was used to conduct the consumer test. The consumers used for this product evaluation were faculty, staff, and students from the Pennsylvania State University (Meilgaard et al., 2007). A 9-point hedonic scale was used to measure overall liking, flavor and texture. A 7-point just-about-right (JAR) scale was used to rate consumer opinions regarding the tenderness and juiciness of the steak samples. All of the evaluations were conducted in individual testing booths.
2.3.5 Statistical analysis

Steaks were utilized for a shear force test and consumer taste test with the same identifying steak number for each test. The proc mixed program within SAS (SAS, 2002) was utilized using weight gain, final weight, frame size, sex, fat thickness, rib-eye area (REA), yield grade, shear force, marbling score, and percentage of kidney, pelvic and heart fat (% KPH) as factors and comparing them with the response variables from the consumer panelists in a backwards elimination procedure. Each of the production and carcass traits were subjected to this analysis with each of the consumer acceptability values (overall liking, flavor, texture, tenderness and juiciness). The production or carcass trait that had the greatest p-value, greater than an alpha level of 0.1, was removed from the model for each iteration. After each variable was removed, the procedure was conducted again until all the variables left in the model contained a p-value less than 0.1. After the final model was determined, a correlation was conducted for those variables that remained in the model to determine the partial correlation coefficient and the standard error of the correlations.
2.4 RESULTS AND DISCUSSION

2.4.1 Consumer evaluations

Figures 2.1-2.3 reflect the pasture analysis for crude protein, total digestible nitrogen, and neutral detergent fiber. These data indicate the pasture quality is adequate for reasonable weight gain. Table 2.1 reflects the summary of pasture separations as a percentage of total dry matter (DM) that included orchardgrass (47.3%), tall fescue (33.3%), legumes (4.23%), and weeds and dead materials (15%). Table 2.2 displays the summary of carcass traits. The variability in these results allowed for a comparison of a wide array of factors. The production and carcass traits were examined with the consumer values for these grass-finished steaks. The mean consumer values are presented in Table 2.3. Frame size, marbling score, and grazing ADG were deleted in the statistical elimination procedure comparing consumer response for overall liking, texture, and tenderness. The correlation matrix is presented in Table 2.4.

The effect of frame size on GFB production is related to fattening rate. Since less feed energy is being expended for animal maintenance as a function of body weight, more fat deposition is allowed in the carcass for smaller frame size. Testimonial standards for GFB production usually indicate smaller frame size in the cattle, but these results indicate that, for cattle harvested at 17-18 mo of age, frame size was not related with consumer acceptability of the cooked product. This observation implies there is tremendous flexibility available for production of GFB for frame size at this harvest endpoint. Likewise, marbling is generally used as the indicator of carcass palatability (Johnson et al., 1988; May et al., 1992; Parrett et al., 1985;
Platter et al., 2003). These data show marbling scores ranging in the low Select to low Choice quality grades will not change consumer values for overall liking, flavor, texture, and tenderness with grass-finished cattle harvested at 17-18 mo of age. However, low select to low choice is a fairly narrow range of carcass quality grades, and no GFB data exists to compare consumer values for palatability beyond this range of quality grades, particularly for grades at middle Choice and higher. There is evidence that quality grade in grain-fed cattle at middle Choice quality grade and higher will result in greater palatability of meat (Tatum et al., 1980), but no data exists to indicate if GFB will have this same result.

Carcass fat thickness, rib-eye area, yield grade, and WB shear force were significantly associated (P < 0.1) with overall liking, texture, and tenderness of these steaks (Table 2.4). The results for fat thickness may explain part of the results for marbling score and frame size in that, as the cattle got fatter, consumer scores were reduced for overall liking, texture, and tenderness within the age and marbling scores in these data. Fat in beef is a significant factor in meat flavor (Dolezal et al., 1985), and these results (Table 2.4) indicate the addition of fat, as a function of increased final weight, may contribute to the off-flavors, which was also shown by other researchers (Xiong et al., 1996) for GFB. Fat thickness also has been shown to be a poor predictor of consumer acceptability in grain-fed cattle (Johnson et al., 1988; May et al., 1992; Parrett et al., 1985). Mean consumer values for flavor (Table 2.2) were moderate; indicating changes in meat flavor for GFB could be negatively impacted by fattening. Since fat thickness is a component of the yield grade equation (Boggs et al., 2006), it follows that as yield grade increases it reflects a higher proportion of fat in the carcass and lower palatability value from the consumer panel for yield grades ranging from 2-3.
Shear force is the objective measure of meat tenderness, and shear force values less than 4.6 kg (Shackelford et al., 1991) are generally shown as “acceptable.” Since meat tenderness is a significant factor in acceptability of cooked beef, it follows that consumers would score steaks with higher shear values as lower in overall liking, texture and tenderness. However, similar to most other comparisons between animal traits and consumer scores for cooked product, the statistical strength of these relationships (fat thickness, rib-eye area, yield grade, and shear force with overall liking, flavor, texture, tenderness, and juiciness) were weak. It is important to note, however, from examination of the correlation coefficient and the standard error that shear force had the highest relationship among carcass and production traits with consumer acceptability.

These data indicate manipulating production and carcass traits for GFB may not influence consumer acceptance of the product. At harvest ages of 17-18 mo, increased fattening may be negatively impacting flavor and tenderness effects of cooked steaks to many consumers. Consumer scores for GFB products outside of low Select to low Choice quality grades and for those cattle harvested over 18 mo of age are not presently known.
Sample dates

Figure 2.1: Crude protein (CP) of pasture over the grazing season

Figure 2.2: Total digestible nitrogen (TDN) of pasture over grazing season

Figure 2.3: Neutral detergent fiber (NDF) of pasture over grazing season
Table 2.1: Summary of pasture separations

<table>
<thead>
<tr>
<th>Pasture Separation</th>
<th>% of total DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weeds/Dead Materials</td>
<td>15.2</td>
</tr>
<tr>
<td>Legumes</td>
<td>4.23</td>
</tr>
<tr>
<td>Tall Fescue</td>
<td>33.3</td>
</tr>
<tr>
<td>Orchard Grass</td>
<td>47.3</td>
</tr>
</tbody>
</table>

Table 2.2: Summary of carcass traits

<table>
<thead>
<tr>
<th>Carcass trait</th>
<th>Mean</th>
<th>Standard error</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kill age (d)</td>
<td>532.9</td>
<td>1.05</td>
<td>519</td>
<td>542</td>
</tr>
<tr>
<td>Cold carcass weight (kg)</td>
<td>273.4</td>
<td>3.617</td>
<td>235.5</td>
<td>309.5</td>
</tr>
<tr>
<td>Grazing average daily gain (kg/d)</td>
<td>0.69</td>
<td>0.03</td>
<td>0.15</td>
<td>0.95</td>
</tr>
<tr>
<td>Frame size</td>
<td>5</td>
<td>0.13</td>
<td>3.6</td>
<td>6.7</td>
</tr>
<tr>
<td>Marbling score&lt;sup&gt;a&lt;/sup&gt;</td>
<td>448</td>
<td>6.6</td>
<td>400</td>
<td>430</td>
</tr>
<tr>
<td>Fat thickness (cm)</td>
<td>0.63</td>
<td>0.04</td>
<td>0.25</td>
<td>1</td>
</tr>
<tr>
<td>Yield grade</td>
<td>2.5</td>
<td>0.05</td>
<td>2</td>
<td>3.3</td>
</tr>
<tr>
<td>Shear force (kg)</td>
<td>4.5</td>
<td>0.25</td>
<td>2.4</td>
<td>8.4</td>
</tr>
<tr>
<td>Ribeye area (cm&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>68.9</td>
<td>0.85</td>
<td>58.7</td>
<td>77.4</td>
</tr>
</tbody>
</table>

<sup>a</sup>500 = small<sup>0</sup>; 400 = slight<sup>0</sup>

Table 2.3: Mean consumer values for grass-finished steaks

<table>
<thead>
<tr>
<th></th>
<th>Overall liking&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Flavor&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Texture&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Tenderness&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Juiciness&lt;sup&gt;3&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>5.00</td>
<td>5.50</td>
<td>4.70</td>
<td>2.71</td>
<td>3.22</td>
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<tr>
<td>Minimum</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Maximum</td>
<td>9.00</td>
<td>9.00</td>
<td>9.00</td>
<td>6.00</td>
<td>5.00</td>
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<tr>
<td>SE</td>
<td>0.22</td>
<td>0.17</td>
<td>0.23</td>
<td>0.12</td>
<td>0.07</td>
</tr>
</tbody>
</table>

<sup>1</sup>Based on a 9-point scale: 9 = like extremely, 5 = neither or dislike, and 1 = dislike extremely.
<sup>2</sup>Based on a 7-point just-about-right (JAR) scale: 7 = much too tender, 4 = just about right, 1 = much too tough
<sup>3</sup>Based on a 7-point just-about-right (JAR) scale: 7 = much too juicy, 4 = just about right, 1 = much too dry
Table 2.4: Significant partial correlation among production and carcass traits with consumer acceptability of grass-finished steaks

<table>
<thead>
<tr>
<th>Effect</th>
<th>Overall liking $^{2}$</th>
<th>Flavor $^{2}$</th>
<th>Texture $^{2}$</th>
<th>Tenderness $^{3}$</th>
<th>Juiciness $^{4}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frame size</td>
<td>-0.20 $^{c}$±0.07</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final weight</td>
<td></td>
<td>-0.19 $^{c}$±0.07</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat thickness</td>
<td>-0.11 $^{c}$±0.07</td>
<td>-0.095 $^{b}$±0.07</td>
<td>-0.11 $^{b}$±0.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ribeye area</td>
<td>-0.016 $^{d}$±0.08</td>
<td>0.044 $^{c}$±0.07</td>
<td>0.040 $^{b}$±0.08</td>
<td>0.11 $^{d}$±0.07</td>
<td></td>
</tr>
<tr>
<td>Yield grade</td>
<td>-0.21 $^{d}$±0.07</td>
<td>-0.28 $^{d}$±0.06</td>
<td>-0.26 $^{d}$±0.07</td>
<td></td>
<td>-0.23 $^{d}$±0.07</td>
</tr>
<tr>
<td>Shear force</td>
<td>-0.26 $^{d}$±0.06</td>
<td>-0.29 $^{d}$±0.06</td>
<td>-0.28 $^{d}$±0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marbling score</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.16 $^{c}$±0.07</td>
</tr>
</tbody>
</table>

$^{1}$Numbers in the table are significant partial correlations coefficients (r) with their corresponding standard error;

$^{2}$Based on a 9-point scale: 9 = like extremely, 5 = neither or dislike, and 1 = dislike extremely.

$^{3}$Based on a 7-point just-about-right (JAR) scale: 7 = much too tender, 4 = just about right, 1 = much too tough

$^{4}$Based on a 7-point just-about-right (JAR) scale: 7 = much too juicy, 4 = just about right, 1 = much too dry

$^{a}$P < 0.1  $^{b}$P < 0.05  $^{c}$P < 0.01  $^{d}$P < 0.001 These p-values are from a previously conducted proc mix.
Reference List


Beef Improvement Federation. 2002. Guidelines for uniform beef improvement programs. 8th Ed. University of Georgia, Athens, GA.


Chapter 3
The Relationship of Fatty Acids and Cholesterol with the Consumer Acceptability of Grass-finished Steaks

3.1 ABSTRACT

Twenty grass-finished steers and 10 grass-finished heifers were evaluated for the relationship of fatty acids and cholesterol with consumer evaluation of tenderness, juiciness, flavor, and acceptability of cooked steaks. The fatty acid analysis was conducted using gas chromatography and the cholesterol analysis was conducted using gas-liquid chromatography.

A longissimus muscle steak from each of the thirty carcasses was thawed, cooked and offered to consumer panelists, and an additional steak was used to determine the total lipid, fatty acid content, and total cholesterol content for each of the steaks. Correlations determined the relationship of fatty acids and cholesterol with the consumer evaluations. Results indicated fatty acid profile and cholesterol content was not strongly related to panelist evaluations of tenderness, flavor, juiciness, meat texture, or overall desirability for grass-finished cattle harvested at 533 d of age. Mean panel scores for grass-finished steaks were moderate for overall liking, flavor, and juiciness, while scoring them slightly tough. Significant variation in scores for tenderness, juiciness, texture, flavor, and overall desirability were found, indicating post-harvest interventions may be more effective in increasing consistency for consumers of grass-finished meat compared to manipulating fatty acids and cholesterol.

(Key words: Grass-finished, beef, fatty acid, cholesterol, consumer)
3.2 INTRODUCTION

Fat and cholesterol content of grass-finished beef GFB has been related to human health factors. However, consumer acceptability has been a major problem for producers of GFB. GFB has been documented as having a strong ($P \leq 0.05$) “grassy” flavor two days post-mortem and developing more ($P \leq 0.05$) of an off-flavor after 10 days of aging, as compared to grain-fed beef (Xiong et al. 1996). Consumers also gave grain-fed beef higher ($P < 0.001$) scores for flavor, juiciness, tenderness, and overall acceptability when compared to GFB (Sitz et al., 2005). It has been speculated that the off-flavor in GFB may be a result of the fatty acid profile and that production and carcass traits may contribute to their fatty acid profile.

However, there are no known studies that examine the relationship of fatty acids and cholesterol with the consumer acceptability in grass-fed steaks. It would be beneficial for producers to know if these relationships exist. Therefore, the objective of this study was to determine whether there is a relationship of fatty acid composition and/or cholesterol with consumer acceptability of cooked steaks.
3.3 MATERIALS AND METHODS

3.3.1 Background

An experiment was conducted with the consent of the Pennsylvania State University Institutional Animal Care and Use Committee (IACUC #20625). A consumer taste test was conducted with the consent of the panelists (IRB #24404). Information regarding the animal care and feeding can be found in Chapter 2. All of the analyses on in this study were conducted using those 20 steers and 10 heifers. The methods used to conduct the consumer taste panel can be found in Chapter 2.

3.3.2 Laboratory analysis

3.3.2.1 Lipid analysis

Fatty acid profiles were conducted in the laboratory of Dr. Susan Duckett at the Department of Animal and Veterinary Science at Clemson University, Clemson, SC. Frozen steaks were packaged in dry ice and sent via Federal Express to Clemson University for next day arrival. The sample preparation, total lipid content, and fatty acid analysis of the meat sample was done using gas chromatography (Park and Goins, 1994). Total cholesterol content of the meat sample was measured using gas liquid chromatography (Du and Ahn, 2002).
3.3.2.1.1 Sample preparation

All longissimus muscle steaks were thawed in a refrigerator at 2-3 °C and prepared for analysis by removal of external fat and connective tissue, and the sample was chopped into cubes. A food processor (Waring ProPrepTM WCG75 Chopper-Grinder, Torrington, CT) was used to process the muscle into smaller particles. Three grams in duplicate were weighed out in small metal pans for dry matter determination in a freeze dryer (VirTis 24x48, Gardiner, NY) at 95ºC for 24 hr. The remaining muscle was immediately placed into a clear plastic storage bag, frozen, and freeze dried in a freeze dryer (VirTis 24x48, Gardiner, NY). A food processor (Waring ProPrepTM WCG75 Chopper-Grinder, Torrington, CT) was used to grind each freeze dried muscle into a powdered sample. The freeze dried sample was then stored in a Whirlpak® bag in a refrigerator at 2-3°C for less than 30 d before analysis.

3.3.2.1.2 Total lipid content

A filter bag was pre-weighed (Mettler-Toledo AB204-S) and recorded. A 0.5 g of the freeze-dried sample was placed into each filter bag in duplicate and weighed. Each filter bag was sealed (AIE-200 Impulse Sealer, American International Electric). The filter bags were then placed on a metal tray, dried at 95 °C for 24 hours, and reweighed. The filter bags were then placed in an Ankom Fat Extractor (Ankom XT15 Fat Extractor, Ankom Technology, Macedon, NY) for 80 minutes (60 min.: hydrolysis; 20 min.: rinsing) with solvent (hexane) and subsequently placed in a hood for 10 min, and then placed in an oven (Precision 6542, Thermo
Electron Corp.) at 95°C for 24 hr. The weight was then recorded and the percent lipid was calculated.

### 3.3.2.1.3 Fatty acid analyses

A sample containing 10 mg of total lipid was weighed out into a test tube. Methylene chloride and 0.5 N sodium methoxide in methanol were added to the each test tube at 500 μl and 1 ml, respectively, flushed with nitrogen, and capped with a Teflon lined cap. The tubes were heated at 90°C for 10 min, and cooled to room temperature (≈23°C). One ml of 14% BF3 was added in methanol. Each tube was then flushed with nitrogen, recapped, and heated at 90°C for 10 min. After cooling to about 23°C, 500 μl hexane containing internal standard (ISTD; 1 μg/μl C23:0) was added to each tube. Two ml of deionized H2O was added to each tube, and was vortexed for 2 min. Each tube was subsequently centrifuged (Sorvall Legend RT) at 1500x g for 5 min, the top layer of each tube was transferred to a test tube, and a small amount of anhydrous sodium sulfate was added. The hexane layer was then transferred to an amber vial, flushed with nitrogen, and capped. Gas chromatography (GC; Agilent 6850) utilized SP2560_FA_100 for long-chain fatty acids and trans-fatty acids and SP2560_FA_10 for CLA and ω-3 fatty acids. The carrier gas was H2 and the make-up gas was N2. Regarding, weight composition of FAME of samples, peak areas were corrected using theoretical FID response factors. Weight percentages of the fatty acids were calculated based on the formula: Long-chain and trans-fatty acid percentage = (((Area\_fatty acid/(Area\_ISTD/0.5mg))/Area\_total-ITSD)×100); CLA and PUFA percentage – (Area fatty acid/(Area\_ITSD/0.5mg))/mg fatty acids).
3.3.2.1.4 Total cholesterol content

A saponification reagent was made fresh daily. Ethanol was mixed in a 33% (w/v) KOH solution at a ratio of 94:6. A 0.4 g sample of freeze dried ground material was weighed into a 50 ml screw cap test tube. Ten ml of saponification reagent was added, and one ml of stigmasterol was added. The solution was vortexed for 30 seconds at full speed. The homogenized solution was incubated at 50°C for 10 min. Ten ml of hexane was added, 10 ml of water was added, each tube was capped, and vortexed for 2 minutes. The tubes were centrifuged at 3000 x g for 30 min. The hexane layer was removed (upper layer) and transferred to another test tube. The hexane was removed under nitrogen. Pyridine and Sylon BFT (99% BSTFA and 1% TMCS) were added at 200 μl and 100 μl, respectively. The sample was incubated in a dry incubator at 50 °C for 1 hr. The GC was used to analyze the cholesterol with HP5_cholesterol by calculating the cholesterol amounts based on the internal standards.

3.3.3 Statistical analysis

Steaks from each animal were utilized for a consumer taste test and to examine the fatty acid profile with the same identifying steak number for each test. Fatty acids and cholesterol were examined to determine which of them were significantly (P < 0.1) related with consumer acceptability. The fatty acids and cholesterol included total lipid (%;gram/100 g), C18:1 trans-11 (gram/100g), fatty acid (%; gram/100 g), saturated fatty acid (%;gram/100g), odd chain fatty
acid (OCFA; %; gram/100 g), monounsaturated fatty acid (MUFA; %; gram/100 g),
polyunsaturated fatty acid (PUFA; %; gram/100 g), ω-6 fatty acid (%; gram/100 g), ω-3 fatty acids
(%; gram/100 g), ratio of ω-6 to ω-3 fatty acids (%; grams/100 g), total conjugated linoleic acid
(cis-9 trans-11 + trans-10 cis-12; CLA; %; gram/100 g), cis-9 trans-11 CLA (%; grams/100 g),
trans-10 cis-12 CLA (%; grams/100 g) and cholesterol (%; grams/100 g). The same statistical
procedure was completed as in Chapter 2 for the fatty acids and cholesterol with each of the
consumer sensory values (overall liking, flavor, texture, tenderness and juiciness).
3.4 RESULTS AND DISCUSSION

3.4.1 Fatty acid and cholesterol analysis

The fatty acids that were measured and subjected to analysis were total lipid (%; g/100 g; Table 3.1 and 3.2), C18:1 trans-11 (vaccenic acid; g/100g; % total fatty acids), fatty acid (%; g/100 g; % total fatty acids), saturated fatty acid (SFA; g/100g; % total fatty acids), odd chain fatty acid (OCFA; g/100g; % total fatty acids), monounsaturated fatty acid (MUFA; g/100g; % total fatty acids), polyunsaturated fatty acid (PUFA; g/100g; % total fatty acids), ω-6 fatty acid (g/100g; % total fatty acids), ω-3 fatty acids (g/100 g; % total fatty acids), ratio of ω-6 to ω -3 fatty acids (g/100g; % total fatty acids), total conjugated linoleic acid (TCLA; g/100g; % total fatty acids), cis-9 trans-11 CLA (g/100g; % total fatty acids), trans-10 cis-12 CLA (g/100g; % total fatty acids), C18:1 trans-11 (vaccenic acid;g/100g; % total fatty acids) and cholesterol (g/100g; % total fatty acids).

None of the fatty acids (total lipid percentage, vaccenic acid, fatty acid percentage, fatty acid concentration, trans-10 cis-12, cis-9 trans-11, TCLA, PUFA, OCFA, MUFA, ratio of ω-6 to ω-3 fatty acids, SFA, and cholesterol) had a statistically significant relationship (P >0.1) with consumer evaluation of overall liking, suggesting fatty acid composition does not relate to consumer acceptability (Table 2.3). This observation implies manipulation of the lipids by changing the diet in these cattle did not improve consumer’s overall liking of these steaks. These results reflect a greater flexibility in production of GFB because of fewer restrictions from carcass traits and animal factors on nutritional and environmental effects to fatty acid composition of the product.
Mean value for flavor among all meat samples was 5.50 with a range of 1.00 and 9.00 (Table 2.3). Variables that did not have a significant relationship ($\alpha = 0.10$) with flavor were deleted in subsequent statistical models in the following order: cis-9 trans-11, OCFA, MUFA, trans-11, and total CLA. Variables that shared a significant relationship ($P < 0.1$) with flavor were SFA ($P < 0.0001$), PUFA ($P = 0.02$), ratio of ω-6 to ω-3 fatty acids ($P = 0.01$), trans-10 cis-12 ($P = 0.01$), total lipid percentage ($P = 0.05$), and cholesterol ($P = 0.01$; Table 3.3). The relationships among these variables (SFA, trans-10 cis-12 CLA, total lipid (%) and cholesterol) with flavor were negative ($r = -0.16$, -0.07, -0.09, and -0.01, respectively; Table 3.3), suggesting increases in these fatty acids and cholesterol content are implicated in lower consumer values for flavor of the product.

A significant motivation for consumers to consume this product is the implied health benefits of CLA (Baumgard et al., 2000; Baumgard et al., 2001; Blankson et al., 2000; Ha et al., 1987; Ip et al., 1999; Lee et al., 2006; Mougios et al., 2001; Pariza et al., 1979; Whigham et al., 2000) and it may have a negative, though very small, result for flavor of the product. Relationships between PUFA and the ratio of ω-6 to ω-3 fatty acids with flavor were positive ($r = 0.07$ and 0.15, respectively; Table 3.3). However, although these fatty acids (SFA, PUFA, ratio of ω-6 to ω-3 fatty acids, trans-10 cis-12 CLA, total lipid percentage, and cholesterol) had significant relationships with meat flavor, they were statistically weak as shown by the correlation index ($r^2$). There does not appear to be a strong association between fatty acid profile and cholesterol content of the meat with consumer values of meat flavor. However, there is a positive relationship between the ratio of ω-6 to ω-3 fatty acids with flavor. SFA was negatively related with consumer acceptability of flavor, while PUFA was positively related with consumer acceptability for flavor. SFA has been linked with coronary heart disease (Kromhout et al.,
In addition to the relationship with flavor, an increase in PUFA was shown to have a negative relationship with the level of juiciness. Juiciness is often associated with the flavor of the beef product; therefore it is a major indicator of consumer acceptability. These data reflect that numerous variables affect consumer acceptability of grass-finished steaks. Therefore, it may be difficult to manipulate the fatty acid and cholesterol profile through genetic, nutritional, or environmental means to improve it.

OCFA, PUFA and TCLA had a negative correlation ($r = -0.20, -0.16, -0.08$, respectively) with juiciness, while $trans$-$10$ cis-$12$ CLA had a positive correlation ($r = 0.01$; Table 3.3). These negative relationships could affect consumer purchasing decisions. However, the correlation index ($r^2$) between these fatty acids with juiciness was weak, as well as the correlation index for $trans$-$10$ cis-$12$ CLA (Table 3.3). The fatty acid profile and cholesterol content does not appear to have an influence on juiciness.

Also, there was no significant relationship of SFA, ratio of $\omega$-$6$ to $\omega$-$3$ fatty acids, total lipid percentage, or cholesterol with the consumer acceptability of texture, tenderness, and juiciness. Although there was a relationship of PUFA and odd chain fatty acid (OCFA), this relationship is weak ($r^2$). This result lends flexibility to nutritional and environmental effects of grass-fed cattle production because these factors will probably not be altered under normal production practices.

The fatty acids that had a significant relationship ($P < 0.1$) with texture were TCLA ($P = 0.03; r = -0.1$) and $trans$-$10$ cis-$12$ CLA ($P = 0.03; r =0.06$; Table 3.3). The negative correlation of meat texture with total CLA again may have implications to consumer buying decisions for GFB as will the positive relationship of $trans$-$10$ cis-$12$ CLA with texture. However, these relationships are statistically weak as shown by the correlation index ($r^2 = 0.01$ and 0.004,
respectively; Table 3.4). Consumer buying decisions for meat are not usually driven by the texture of the product unless there are extreme values.

The mean value for tenderness was 2.71 with a range of 1.00 to 6.00 (Table 2.3). Tenderness is one of the most important characteristics of meat acceptability by consumers. The fatty acids removed in the elimination procedure, in the order of deletion from statistical models, for tenderness were cholesterol, C18:1 trans-11, cis-9 trans-11, total lipid percentage, OCFA, the ratio of ω-6 to ω-3 fatty acids, MUFA, PUFA and SFA. The remaining fatty acids in the model that had a significant relationship (P < 0.1) with consumer acceptability for tenderness were TCLA (P = 0.04; r = -0.08) and trans-10 cis-12 (P = 0.04; r = 0.07; Table 3.3). The negative relationship between tenderness and CLA content could have an impact on consumer buying decisions. However, the correlation coefficient for these two factors was again very small (r² = 0.001) and weak, as was the coefficient between tenderness and trans-10, cis-12 (r²=0.005; Table 3.3). The current study agreed with Duckett et al. (1993) which combined the fatty acid data with taste panel data from May et al. (1992). The results indicated oleic acid had a positive but weak relationship with tenderness (r = 0.33; r² = 0.11) and flavor (r = 0.39; r² = 0.15) and had a negative but weak relationship with WBS values (r = 0.50; r² = 0.25). PUFA had a negative but weak relationship with tenderness (r = -0.49; r² = 0.24) and flavor (r = -0.35; r² = 0.12) and a positive and moderate relationship with WBS values (r = 0.66; r² = 0.44). SFA did not have any significant (P > 0.05) relationships with the taste panel data (Duckett et al., 1993). The level of desirable perceived health characteristics in the fatty acid profile and cholesterol content may not have a negative influence on important factors of acceptability of the cooked product.
Table 3.1: Summary table for fatty acid and cholesterol profile of GFB (g/100 g sample)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SE</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatty acid (mg/g)</td>
<td>82.3</td>
<td>4.1</td>
<td>47.7</td>
<td>130.1</td>
</tr>
<tr>
<td>Saturated fatty acid</td>
<td>0.03</td>
<td>0</td>
<td>0.02</td>
<td>0.06</td>
</tr>
<tr>
<td>Odd chain fatty acid</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Monounsaturated fatty acid</td>
<td>0.03</td>
<td>0</td>
<td>0.02</td>
<td>0.05</td>
</tr>
<tr>
<td>Polyunsaturated fatty acid</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0.01</td>
</tr>
<tr>
<td>ω-6 Polyunsaturated fatty acid</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ω-3 Polyunsaturated fatty acid</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ratio of ω-6:ω-3 Polyunsaturated fatty acids</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total conjugated linoleic acids</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cis-9 trans-11 conjugated linoleic acid</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total trans fatty acids</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Trans-11 fatty acid</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Trans-10 cis-12 conjugated linoleic acids</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>0.05</td>
<td>0</td>
<td>0.04</td>
<td>0.06</td>
</tr>
</tbody>
</table>
Table 3.2: Summary table for fatty acid and cholesterol profile of GFB

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SE</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatty acid (mg/g)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.2</td>
<td>0.41</td>
<td>4.8</td>
<td>13</td>
</tr>
<tr>
<td>Total lipid&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.25</td>
<td>0.43</td>
<td>6.4</td>
<td>15</td>
</tr>
<tr>
<td>Saturated fatty acid&lt;sup&gt;a&lt;/sup&gt;</td>
<td>42.3</td>
<td>0.35</td>
<td>39.3</td>
<td>47</td>
</tr>
<tr>
<td>Odd chain fatty acid&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.38</td>
<td>0.06</td>
<td>0.79</td>
<td>2.4</td>
</tr>
<tr>
<td>Monounsaturated fatty acid&lt;sup&gt;a&lt;/sup&gt;</td>
<td>39.6</td>
<td>0.36</td>
<td>34.3</td>
<td>42.7</td>
</tr>
<tr>
<td>Polyunsaturated fatty acid&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.3</td>
<td>0.22</td>
<td>4.4</td>
<td>8.6</td>
</tr>
<tr>
<td>ω-6 Polyunsaturated fatty acid&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.2</td>
<td>0.16</td>
<td>3</td>
<td>5.8</td>
</tr>
<tr>
<td>ω-3 Polyunsaturated fatty acid&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.1</td>
<td>0.08</td>
<td>1.3</td>
<td>3</td>
</tr>
<tr>
<td>Ratio of ω-6:ω-3 Polyunsaturated fatty acids&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2</td>
<td>0.06</td>
<td>1.2</td>
<td>2.6</td>
</tr>
<tr>
<td>Total conjugated linoleic acids&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1</td>
<td>0.04</td>
<td>0.63</td>
<td>1.4</td>
</tr>
<tr>
<td>Cis-9 trans-11 conjugated linoleic acid&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.6</td>
<td>0.03</td>
<td>0.28</td>
<td>0.94</td>
</tr>
<tr>
<td>Total trans fatty acids&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.8</td>
<td>0.12</td>
<td>1.8</td>
<td>4.4</td>
</tr>
<tr>
<td>Trans-11 fatty acid&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.6</td>
<td>0.11</td>
<td>1.5</td>
<td>3.8</td>
</tr>
<tr>
<td>Trans-10 cis-12 conjugated linoleic acids&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.08</td>
<td>0</td>
<td>0.04</td>
<td>0.12</td>
</tr>
<tr>
<td>Cholesterol&lt;sup&gt;b&lt;/sup&gt;</td>
<td>52.8</td>
<td>1.27</td>
<td>41.4</td>
<td>63.1</td>
</tr>
</tbody>
</table>

<sup>a</sup>Based on % of total fatty acids.

<sup>b</sup>Moisture basis.

Table 3.3: Significant partial correlation among fatty acids and cholesterol with consumer acceptability of GFB

<table>
<thead>
<tr>
<th>Effect</th>
<th>Flavor&lt;sup&gt;12&lt;/sup&gt;</th>
<th>Texture&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Tenderness&lt;sup&gt;3&lt;/sup&gt;</th>
<th>Juiciness&lt;sup&gt;4&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturated fatty acid</td>
<td>-0.17±0.07</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyunsaturated fatty acid</td>
<td>0.066±0.07</td>
<td></td>
<td>-0.16±0.07</td>
<td></td>
</tr>
<tr>
<td>Ratio of ω-6 to ω-3 polyunsaturated fatty acid</td>
<td>0.16±0.07</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C18:2 trans-10 cis-12 conjugated linoleic acid</td>
<td>-0.075±0.07</td>
<td>0.060±0.07</td>
<td>0.074±0.07</td>
<td>0.097±0.07</td>
</tr>
<tr>
<td>Total lipid (%)</td>
<td>-0.088±0.07</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cholesterol</td>
<td>-0.013±0.07</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total conjugated linoleic acid</td>
<td>-0.10±0.07</td>
<td>-0.081±0.07</td>
<td>-0.082±0.07</td>
<td></td>
</tr>
<tr>
<td>Odd chain fatty acid</td>
<td></td>
<td></td>
<td></td>
<td>-0.20±0.07</td>
</tr>
</tbody>
</table>

<sup>1</sup>Numbers in the table are significant partial correlations coefficients (r) with their corresponding standard error

<sup>2</sup>Based on a 9-point scale: 9 = like extremely, 5 = neither or dislike, and 1 = dislike extremely.

<sup>3</sup>Based on a 7-point just-about-right (JAR) scale: 7 = much too tender, 4 = just about right, 1 = much too tough

<sup>4</sup>Based on a 7-point just-about-right (JAR) scale: 7 = much too juicy, 4 = just about right, 1 = much too dry

<sup>a</sup>P < 0.1<sup>b</sup>P < 0.05<sup>c</sup>P < 0.01<sup>d</sup>P < 0.001 P-values are from a previously conducted proc mix.
Reference List


Chapter 4

The Relationship of Animal, Production and Carcass Traits with Fatty Acids and Cholesterol of Grass-Finished Steaks

4.1 ABSTRACT

Twenty grass-finished steers and 10 grass-finished heifers were evaluated for the relationship of wintering growth rate, daily BW gain, sex, grazing period, frame size, final weight, and carcass traits (fat thickness, ribeye area, marbling score, and yield grade) with the fatty acid and cholesterol profile of the uncooked steaks. All of the cattle were wintered for a targeted weight gain of 0.73 kg/d for 156 d, and then were grazed in rotationally-grazed paddocks containing primarily cool-season grasses. Cattle were harvested at a constant age (532.9 d ± 5.7 d) in 6 harvest groups ranging from 124 d to 187 d of grazing and carcass data was collected. Six longissimus muscle steaks were taken from each of the thirty carcasses, and one of the steaks from each of the carcasses was used to determine the total lipid, total cholesterol, and fatty acid content of each of the steaks. Correlations were conducted to determine the relationship of animal, production and carcass traits with fatty acids and cholesterol. Results indicated animal, growth, and carcass traits were not strongly related with the fatty acids and cholesterol for grass-finished cattle harvested at 532 d of age.

(Key words: Grass-finished, beef, carcass, fatty acid, cholesterol)
Grass-fed beef (GFB) has been receiving a great deal of attention among health-conscious consumers. This attention can be partially attributed to data reflecting GFB had significantly higher concentrations of conjugated linoleic acids (CLA) when compared to grain-fed beef (French et al., 2000), and documented influencing immune response, being anticarcinogenic, and antiatherogenic (Baumgard et al., 2000; Ip et al., 1999; Lee et al., 2006; Whigman et al., 2000). In addition, fatty acid profiles are improved and there is less saturated fat in the product (Duckett and Pavan, 2007).

Studies have reflected that there is a preference for grain-fed beef when compared with grass-fed beef (Martz, 2000), but there are few studies that singularly examine grass-fed beef. A market may exist for grass-finished beef (Fuez and Umberger 2008; Kerth et al., 2004). A study was conducted by Malau-Aduli et al. (2000), from 1994 to 1996, to analyze the relationships between fatty acid composition, marbling score, and melting point. The data were collected from the adipose tissue of 764 Angus, Belgian Blue, Hereford, Jersey, Limousin, South Devon, and Wagyu crossbred cattle slaughter after lot-feeding at 500 d. of age. Marbling score had a strong negative relationship (r = -0.71) with the stearate and a medium genetic correlation (r = 0.38) between marbling and oleate, suggesting that marbling is related to the fatty acid composition in the adipose tissue of beef cattle (Malau-Aduli, 2000). The objective of this study was to identify the relationship between production and carcass traits of grass-finished cattle and fatty acid composition and/or cholesterol in the meat.
4.3 MATERIALS AND METHODS

4.3.1 Background

An experiment was conducted with the consent of the Pennsylvania State University Institutional Animal Care and Use Committee (IACUC #20625). The experiment consisted of 20 grass-finished steers and 10 grass-finished heifers. All of the cattle were wintered together postweaning for a targeted weight gain of 0.73 kg/d for 156 d. The cattle were progeny of Angus/Simmental crossbred cows that ranged from 25% to 88% Angus, and all cattle were sired by Angus bulls both AI and naturally with 9 sires represented. The animal feeding and management for the summer and winter feeding can be found in Chapter 2. Cattle harvest information, production and carcass trait collection, and shear force methods may be found in Chapter 2. The methods for the lipid and cholesterol analysis can be found in Chapter 3 with the same fatty acids and cholesterol.

4.3.2 Statistical analysis

The proc mixed program in SAS (SAS, 2002) was utilized to evaluate bodyweight gain, final weight, frame size, sex, yield grade, grazing days, fat thickness, rib-eye area (REA), marbling score, and percentage of kidney, pelvic and heart fat (% KPH) as factors and comparing them with the fatty acid and cholesterol profile. The same statistical procedure was completed as in Chapter 2 for the production and carcass traits with each of the fatty acids and cholesterol.
4.4 RESULTS AND DISCUSSION

4.4.1 Carcass quality trait summary

Carcass traits that were examined and analyzed were sex, frame size, grazing average daily gain (kg), final weight (kg), fat thickness (cm), ribeye area (cm²), yield grade, marbling score, and shear force (kg). These variables had considerable variation at age-constant harvest points (Table 2.2). The variations within the fatty acid profile were minimal (Tables 3.1 and 3.2) which may be expected because they were all fed the same forages under similar environmental conditions.

4.4.2 Fatty acid profile

Total lipid was reported on a percentage of DM basis with a mean of 10.3% and a range of 6.4 to 14.5%. Yield grade, grazing average daily gain, frame size, final weight, harvest group, and fat thickness were removed when comparing total lipid ($\alpha = 0.1$) indicating these traits did not influence total lipid percent in GFB meat at an age-constant endpoint. The traits with a significant relationship ($P < 0.1$) with total lipid were sex and marbling score (Table 4.1). Marbling score had a positive correlation with total lipid. It is not surprising that as marbling score increases so does the total lipid, as well as fatty acid and monounsaturated fatty acids. This relationship was found to be moderately strong as measured by correlation index ($r^2 = 0.36$).

Fatty acids were reported on a percent of total DM basis with a mean of 8.2% and a range of 4.8 to 13%. Yield grade, final weight, grazing average daily gain, frame size, harvest group,
fat thickness, and sex were not related to \( P > 0.1 \) fatty acid percentage. This finding indicates the fatty acid profile in this GFB was not influenced by variation among these traits. Therefore, within the ranges of this study, it is not necessary for producers to limit animal weight, frame size, or fattening rate of cattle to influence the fatty acid profile in the cooked product. The trait that had a significant relationship \( P < 0.1 \) with fatty acid percentage was marbling score (Table 4.1). The relationship of marbling score with fatty acid percentage and monounsaturated fatty acids (MUFA) was positive (Table 4.1). As shown previously, it is not surprising that these fatty acids increased with an increased level of marbling. There was a significant relationship of marbling score with fatty acid (%) and the relationship was moderately strong as measured by correlation index \( r^2 = 0.4 \). As the level of marbling increased the amount of PUFA decreased, which is not an improvement from a human health perspective. Even though marbling score had a moderately strong relationship with these fatty acids, it would lead to incremental changes within the fatty acid profile. Therefore, changing the marbling score would not necessarily influence the fatty acid profile.

C18:1 _trans-11_ (vaccenic acid) was reported on a grams/100 gram basis with a mean of 0.002 and a range of 0.001 to 0.004 g/100g of sample. Vaccenic acid was not related with any of production and carcass factors. The exception was harvest group (grazing days). This observation may be occurring because there is a very small concentration of C18:1 _trans-11_ fatty acid within the sample (Table 3.1 and 3.2) and desaturation of C18:1 _trans-11_ to _cis-9 trans-11_ within the mammary tissue (Griinari et al., 2000). Harvest group (Table 4.1) had a positive correlation with C18:1 _trans-11_. However _cis-9 trans-11_ fatty acid did not have a relationship with harvest group. This finding suggests that C18:1 _trans-11_ increased with the amount of time the animals grazed at a faster rate then the desaturation to _cis-9 trans-11_ fatty acid for 124 to 187
d of grazing. C18:1 trans-11 fatty acids have been linked to coronary heart disease and are found in meats and animal fats, particularly ruminants (Lai and Lo, 2006). CLA may reduce the incidence of coronary heart disease by reducing body weight (Blankson et al., 2000). Although this relationship was significant, the relationship was weak as measured by correlation index ($r^2 = 0.12$).

Harvest group had a negative relationship with the ratio of $\omega$-6 to $\omega$-3 fatty acids, meaning that as the days of grazing increased the ratio of $\omega$-6 to $\omega$-3 fatty acids decreased. The average American diet has changed from an equal ratio of $\omega$-6 to $\omega$-3 fatty acids (0.1-2.8) during the hunter/gatherer era to a ratio of 3.3 to 16.7 in the industrial era (Heller et al., 2005). Increasing the length of time of grazing prior to harvest decreases the ratio (or decreasing the levels of $\omega$-6 fatty acids) is a positive human health issue because these two fatty acids compete with one another to be converted into active metabolites in the body (Medline Plus (Author unknown), 2006).

Both CLA isomers (Trans-10 cis-12 and cis-9 trans-11) were reported as grams/100 grams of sample and were not significantly related ($P > 0.1$) with any of the carcass traits (Table 3.1 and Table 3.2). This result may be due to the low concentration of CLA within these GFB samples. Trans-10 cis-12 has been shown to reduce milk fat percentage (Baumgard et al., 2000; Baumgard et al., 2001), induce apoptosis of colorectal tumors (Lee et al., 2006), in combination with cis-9 trans-11, reduces body fat mass in overweight and obese humans (Blankson et al., 2000), as well as reduces body fat and mass in non-obese (BMI < 30 kg m$^2$; (Mougios et al., 2001). Cis-9 trans-11 has been found to reduce the incidence of mammary tumors (Ip et al., 1999). Manipulating the carcass traits does not appear to influence the outcome levels of these CLA isomers.
Total CLA had a mean of 0.001 with a range of 0.000 to 0.002 grams/100 g sample. None of the traits were significantly related to (P > 0.1) total CLA. This result indicates the variation in live animal and carcass traits may not influence the total CLA concentrations within these GFB samples. Under the conditions of this study it appears GFB grazed for at least 124 d and harvested at 17-18 mo of age may not vary in total CLA content of the meat. CLA content has reported human health benefits from studies conducted in mice (Ha et al., 1987; Pariza et al., 1979), rats (Ip et al., 1999; Whigman et al., 2000), human colorectal cancer cells (Lee et al., 2006), and humans (Blankson et al., 2000; Mougios et al., 2001), albeit at intake levels that are considerably different than those found in the products in the present study (0.001g/100 g sample of total CLA in uncooked meat versus .03g/ 100g of free CLA in clinical studies). Research to examine variable rates of CLA intake in human health is needed to confirm if the level in cooked meat from GFB has any benefit to consumers.

PUFA was recorded as grams/100 g sample with a mean of 0.005 g and a range of 0.004 to 0.006g. Grazing average daily gain, harvest group, fat thickness, sex, and final weight were not found to be statistically significant (P > 0.1) with PUFA and MUFA. PUFA was calculated by taking the sum of all the polyunsaturated fatty acids, including \( \omega-6 \) and \( \omega-3 \) fatty acids, which have been shown to have several benefits (Duckett and Pavan, 2007). However, since they do not have a significant relationship with harvest group (days grazing), fat thickness or final weight in these samples, it would be difficult to obtain the concentrations necessary to achieve those benefits.

On the other hand, days grazing (harvest group) did have a significant relationship with the ratio of \( \omega-6 \) to \( \omega-3 \) polyunsaturated fatty acids. This correlation with the ratio of \( \omega-6 \) to \( \omega-3 \) fatty acids was negative (\( r = -0.53 \); Table 4.1). In addition, grazing average daily gain, fat
thickness, and yield grade had a negative relationship with \( \omega-6 \) to \( \omega-3 \) polyunsaturated fatty acids (Table 4.1). This finding suggests that increased days grazed (124 d to 187 d), average daily BW gain, and carcass fat thickness would contribute to a lower ratio of \( \omega-6 \) to \( \omega-3 \) fatty acids. This finding has positive results for human health (Medline Plus (Author unknown), 2006). Frame size was positively correlated with the ratio of \( \omega-6 \) to \( \omega-3 \) fatty acid \( (r = 0.34) \). There was also moderately strong relationship of these fatty acids with harvest group, fat thickness, yield grade, and grazing average daily gain (kg/d) as measured by the correlation index (Table 4.1).

The traits that were significantly related \((P < 0.1)\) to PUFA were frame size, yield grade, and marbling score (Table 4.1). The positive relationship of frame size with PUFA (Table 4.1) indicates increased amount of PUFA in these steaks. This relationship was also seen when comparing frame size with the ratio of \( \omega-6 \) to \( \omega-3 \) PUFA, indicating the increase may be attributable to an increase in the \( \omega-6 \) fatty acids. There was a negative correlation of these traits for yield grade and marbling score (Table 4.1). As marbling score increased the amount of PUFA decreased. Interestingly, the amount of monounsaturated fatty acids increased as the level of marbling increased. This finding may be explained by the addition of fat from increasing the level of marbling. However, the strength of these relationships was not strong; therefore, it is difficult to say whether they had anything to do with one another. Final weight had a negative relationship with MUFA. Since the only information available is the amount of fatty acids involved and the weight, without indications of how much is coming from fat or muscle, further analysis of the weight is needed before explaining this phenomenon.

Even though yield grade and fat thickness were not significantly related, the two major components of yield grade are fat thickness and ribeye area were significantly associated with harvest group (time spent grazing). As the cattle grazed longer, they got fatter and yield grade
increased without changing the final weight. However, the total PUFA and ω-6 PUFA were increased at a slower rate than the ω-3 PUFA.

SFA were reported as grams/100 g sample of meat with a mean of 0.04 g and a range of 0.02 to 0.06 g. Marbling score, sex, yield grade, grazing average daily gain, frame size, and harvest group were not significantly related (P > 0.1) to SFA. The traits that were significantly related (P < 0.1) with SFA were final weight and fat thickness (Table 4.1). Correlations for final weight and fat thickness with SFA were positive (r = 0.51 and 0.15, respectively; Table 4.1). Final weight and increased fat thickness contribute to higher total fat in the carcass resulting in the relative increase in SFA. Coefficients of determinations for these traits (Table 4.1) are moderate to weak indicating weight changes and carcass fat thickness within the limits of this study would not effectively change SFA. The level of SFA in the product (maximum level of 0.45 mg/3 oz serving of meat) is lower than the recommended daily allowance (RDA) of 2 g of saturated fatty acids.

Cholesterol was reported on a gram/100 g meat sample basis with a mean of 0.05 g and a range of 0.04 and 0.06 g. Fat thickness, grazing ADG, frame size, harvest group, yield grade, marbling score, and sex did not have a significant relationship (P > 0.1) with cholesterol. The level of cholesterol in a 100 g portion of product from this study was lower than the FDA’s recommended daily intake for most consumers (300 mg; (HHS and USDA, 2005), and this level is reported to be similar for grain- and grass-fed beef (Duckett and E.Pavan, 2007). Final weight had a significant and positive relationship (P < 0.1) with cholesterol (Table 4.1). As the final weight increases so does the amount of carcass fat within frame size and nutritional level (Boggs et al., 2006). Fat may influence the lipoproteins that carry cholesterol throughout the body, so it is not surprising that an increased final weight would result in increased cholesterol content in
the product. Fat generally is not associated with cholesterol content of lean tissue since it is a structural component of cells. Venison has high levels (95 mg/3 oz) of total cholesterol among the most popular meats, and beef is moderate (73 mg/3 oz; Hansen and Hemmelgarn, 1998). The relationship of cholesterol content and final weight was weak as measured by correlation index ($r^2 = 0.12$; Table 4.1) indicating this production system and harvest endpoints for GFB may not influence cholesterol content of the meat. This result allows more flexibility of production of GFB without compromising important product features to consumers. In conclusion, although some production and carcass traits were moderately related with the fatty acid and cholesterol profile, changes to these traits may only lead to incremental changes to the profiles.
Table 4.1

Table 4.1: Significant partial correlation among fatty acids and cholesterol with production and carcass traits of GFB

<table>
<thead>
<tr>
<th>Effect</th>
<th>Total lipid (%)</th>
<th>C18:1 trans-11 (%)</th>
<th>Fatty acid (%)</th>
<th>Polyunsaturated fatty acids</th>
<th>Monounsaturated fatty acid</th>
<th>Ratio of ω-6 to ω-3 fatty acids</th>
<th>Satuated fatty acid</th>
<th>Cholesterol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marbling score</td>
<td>0.60^a±0.12</td>
<td>0.64^a±0.11</td>
<td>-0.54^a±0.13</td>
<td>0.44^a±0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harvest group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.53±0.14</td>
<td></td>
</tr>
<tr>
<td>Frame size</td>
<td></td>
<td></td>
<td>0.27±0.15</td>
<td>0.34^c±0.21</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield grade</td>
<td></td>
<td></td>
<td>-0.12±0.14</td>
<td>-0.21^b±0.22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final weight</td>
<td></td>
<td></td>
<td>-0.56^c±0.12</td>
<td>0.51^a±0.15</td>
<td>0.35^a±0.19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat thickness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.16^b±0.21</td>
<td>0.15±0.20</td>
</tr>
<tr>
<td>Grazing average daily gain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.57±0.11</td>
<td></td>
</tr>
</tbody>
</table>

^Numbers in the table are significant partial correlations coefficients (r) with their corresponding standard error.

^aP < 0.1 ^bP < 0.05 ^cP < 0.01 ^dP < 0.001 P-values are from a previously conducted proc mix.
Reference List


Chapter 5

Production and Economic Benchmarks for Northeastern Grass-Fed Beef Farms

5.1 ABSTRACT

Twenty-six grass fed beef producers were surveyed in Pennsylvania, New York and Maryland. Surveys lasted about an hour and most of them were done at the producers’ farms, while a few were done by telephone. The surveys were conducted to examine annual production economics and develop benchmark production and economic standards for the enterprise and determine productivity and profitability of production and marketing. The farms varied in size from producers who had 4.0 ha to producers with 145.7 ha of grazing (mean = 29.1 ha) for grass-fed cattle. Production ranged from two grazing animals intended for harvest, to producers who had 75 cattle harvested per year (mean = 21.4). A majority of the producers reported that total farm cattle sales were from grass-fed beef (Mean = 86.6%). Nearly half of the producers reported that cattle sales represented 10-25% of the total farm and non-farm income (Mean = 42.3% of producers).

Most of the producers reported that their cattle graze forages with grass/legume combinations (Mean = 61.1%). The predominant cattle breed was Angus. A majority of the producers are not using preventative vaccines (Mean = 48.1 %) and they do not have any major health problems, with a mean annual health cost per grazed animal of $11.22. The mean age at harvest was 21.4 months, with a minimum age of 14 months and a maximum age of 27 months. The mean live weight at harvest was 498 kg, the mean cost of production per steer was $1,706.02, with a breakeven value of $3.43/kg.
Correlations were calculated on net returns to land and labor and gross income with equipment cost, purchased feed cost, land cost, and cost per steer. Lowering the equipment, purchased feed, and land costs, while increasing the returns per steer, may improve net returns to land and labor and gross income of the farm.

(Keyword: Grass-fed, economic benchmark, production)
5.2 INTRODUCTION

Grass-fed beef producers are attempting to meet the needs of health-conscious consumers. This occurrence has been accomplished because there is data reflecting that GFB had significantly higher concentrations of conjugated linoleic acids (CLA) when compared to grain-fed beef (French et al., 2000), and GFB has documented improved immune response, anticarcinogenic in rats, and antiatherogenic factors (Baumgard et al., 2000; Ip et al., 1999; Lee et al., 2006; Whigman et al., 2000). In addition, fatty acid profiles are improved and there is less saturated fat in the product (Duckett and Pavan, 2007). In addition, consumers find value in knowing the region of origin, breed, traceability, and animal feed (Mennecke et al., 2007). Observational data from Cravey (2007) indicates that there is a higher cost of production compared to grain-fed, and Williams (2007) quotes an AMI consumer survey demonstrating 17% more consumers purchased natural/organic meats since 2006.

Although there is increased interest in grass-fed beef production, producers are struggling to make a profit and improve productivity. This phenomenon is occurring because there is little economic and production data to support production decisions, with most data from their own experience and observations. Although observational data can be very beneficial, there have not been any studies conducted to develop production and economic benchmarks for grass-fed beef producers. Producers can use this information to improve their production system and compare their values with other producers. Therefore, the objective of this study was to determine the production and economic benchmarks of grass-finished beef production by examining the costs and returns in 2006 from 26 grass-fed beef farms in Northeastern US.
5.3 MATERIALS AND METHODS

5.3.1 Grass-finished beef survey

Twenty-six grass-fed beef producers were selected from nominations by county extension educators and from open invitations to members of grazing and grass-fed groups in the Mid-Atlantic region. Selected producers were from Pennsylvania, New York and Maryland. The surveys were conducted in January of 2007. The surveys consisted of 13 sections describing the economic and production values for grass-fed beef harvested in 2006, and included the size of the farm, pastures, maintenance of the farm, the number of cattle, cattle breed, cattle harvest, processing, marketing, reasons they are producing grass-fed beef, and problems they encounter while producing grass-fed beef (Appendix A). The survey results were used to calculate annual per animal costs for pasture and forage maintenance, facilities (including fencing), equipment, health, purchased feeds, wintering programs, pricing for products, and advertising (printed fliers, newspaper/magazine ads, website, farm tour, presentation, mailing, membership). Surveys lasted about an hour and most of them were done at the producers’ farms, while a few were done by telephone, due to time constraints and weather. Survey participants were provided verbal information regarding incentives. These incentives were awarded to five producers and included $500 for each producer, which would used to implement improvements for their grass-fed beef operation. Additional incentives were found on the IRB form provided to participants, and included a statement regarding the benefits of this survey, which served to improve productivity, profitability, and marketing methods. All data was provided by participants and not adjusted by
the investigators. Land and machinery costs were based on participant’s estimate of current value.

5.3.2 Analysis

The information regarding the size of the farm, the pasture, the maintenance of the farm, the number of cattle, the cattle breed, cattle harvest, processing, marketing, reasons they are producing grass-fed beef, and problems they encounter while producing grass-fed beef, was summarized by calculating the mean (sum of all the farms/number of farms who answered), and reported as median, minimum, and maximum values.

The annualized land cost per grazed animal intended for harvest was calculated using the estimated asset value of the land, total acres of the farm, total hectares in grass-fed beef intended for harvest production, and the number of grazed animals intended for harvest production in 2006 using the following equation:

\[
\text{Eq. 5.1 Land cost per animal/yr} = \frac{(((\text{Land Asset}/(\text{total acres of grazing+crop}))*\text{GFB acres})*0.05)/(#\text{grazed animals intended for harvest in 2006}))}{5.1}
\]

The following numbers used in these formulas are from the 2006 Pennsylvania Machinery Custom Rates guide (Jordan, 2006). The establishment cost for each of the forages, except native grasses, were calculated using $33.38/ha (custom rate for planting), $179.20/ha (custom rate for alfalfa), $67.20/ha (custom rate for grass), 20 (years the grass will remain there), total number of cattle on the farm in 2006, and % of hectares that are a specific forage. The following equation was used to estimate establishment costs per animal:
Eq. 5.2 Establishment cost per animal

$$\frac{((33.38+179.20+67.20) \times \text{# of ha intended for GFB in 2006})}{(\text{stand life yr}) \times (\text{total # of cattle on farm in 2006}) \times (\% \text{ of ha that are a specific forage})}$$

The cost of mowing per animal was calculated using $49.14/ha, # of ha bush hogged, and total number of cattle on the farm in 2006.

Eq. 5.3 Cost for mowing

$$\frac{($49.14) \times (\text{# ha bush hogged})}{(\text{total # of cattle on farm in 2006})}$$

The cost of spreading manure was calculated using the total number of acres in grass-fed beef intended for harvest production divided by the total acres of grazing, total number of cattle on the farm in 2006, and $48.16/ha (custom rate).

Eq. 5.4 Cost of spreading manure

$$\frac{(\text{total # of ha in GFB for harvest production/total ha of grazing}) \times (\text{total # GFB on farm in 2006})}{(\text{total # of cattle on farm in 2006}) \times (48.16)}$$

The cost of fencing was calculated using the initial cost of fencing estimated by the producers, 20 yr (estimated life of the fence), total number of cattle on the farm in 2006, % of time that only the cattle are using the land.

Eq. 5.5 Fence cost

$$\frac{(\text{initial fence cost}/20)}{(\text{total # GFB on farm in 2006}*\% \text{ of time only cattle use land})}$$

The cost of irrigation was calculated using a $4.48 per ha charge, total acres in GFB intended for harvest production, and the total number of cattle on the farm in 2006.

Eq. 5.6 Irrigation cost
The cost of equipment was calculated using the producer’s estimated cost and the total number of cattle on the farm in 2006. Estimated remaining life was 20 yr. for equipment less than 10 yr. old and 10 yr. for equipment that was more than 10 yr. old to maintain consistency of cost estimates. If there was more than one piece of the same equipment, each piece was calculated as previously stated and then added together.

Eq. 5.7 Total equipment cost

\[
((\text{current price} - (\text{current price} \times 0.05))/\text{yr. of life left})/\text{total cattle # on farm in 2006}
\]

Deworming cost was calculated using the producer’s estimated cost and the total number of cattle on the farm in 2006.

Eq. 5.8 Deworming cost

\[
(\text{deworming cost})/\text{total # of cattle on farm in 2006}
\]

Purchased feed cost was calculated by adding together the cost for minerals, grain by-products, grain, and food by-products. Since purchased feeds could not be separated among all cattle on the farm, the following formula was used: weight at turnout and a 1000-lb constant value assigned to cows as functions of relative feed intake.

Eq. 5.9 Purchased feed cost

\[
((\text{purchased feed cost})/\text{total # cattle on farm in 2006}) \times (\text{cattle weight at turnout} \times \# \text{GFB intended for harvest production}) / (\text{cattle weight at turnout} \times \# \text{GFB intended for harvest production}) + (\text{total # of cow-calf units} \times 1000)
\]

The wintering costs for hay and balage were calculated by adding together the producer’s estimated cost of the hay and balage. Since winter feed usage could not be separated among all cattle on
the farm, the following formula was used: weight at turnout and a 1000-lb constant value assigned to cows as functions of relative feed intake.

**Eq. 5.10 Wintering costs**

\[ \text{Wintering costs} = \frac{((\text{Hay or balage cost})/\text{(total # cattle on farm in 2006)}) \times ((\text{cattle weight at turnout} \times \# \text{ GFB intended for harvest production})/ \text{(cattle weight at turnout} \times \# \text{ GFB intended for harvest production}) + (\text{total # of cow-calf units} \times 1000))}{\text{GFB intended for harvest production}} \]

The advertising costs were calculated using the producer’s estimated costs and the number of GFB intended for harvest.

**Eq. 5.11 Advertising cost**

\[ \text{Advertising cost} = \frac{\text{(Estimated cost)}}{\text{(# GFB intended for harvest)}} \]

The gross income for cattle intended for harvest was calculated using the average live weight at harvest, % sold by the pound on live weight and average price, % sold by the pound on hot carcass weight (HCW; constant dressing percentage of 60% live weight) and average price, % sold by the pound on retail cuts (using a constant value of 40% of the live weight) and average price, and % sold by the pound on package of cuts (40% of live weight) and average price.

**Eq. 5.12 Live weight value**

\[ \text{Live weight value} = \text{average live weight at harvest} \times \% \text{sold by the pound on live weight basis} \times \text{average price/lb for live weight} \]

**Eq. 5.13 Hot carcass weight value**
average live weight at harvest * 60% * % sold by the pound for HCW * average price/lb for HCW

Eq. 5.13

Retail cut value

(average live weight at harvest * 40% * % sold by the pound for retail cuts * average price/lb for retail cuts)

Eq. 5.14

Package of cuts value

average live weight at harvest * 40% * % sold by the pound on package of cuts * average price/lb for package of cuts)

Eq. 5.15

The gross income was calculated by calculating the sum of the live weight value, hot carcass weight value, retail cut value, and package of cuts value.

The annual per animal cost was calculated from the annual per animal costs for pasture and forage maintenance, facilities (fencing and cattle handling chutes and corrals), equipment, health, purchased feeds, wintering programs (dry hay and balage), and advertising. The net returns were calculated as the difference between annual gross income per animal and annual per animal cost.
5.4 RESULTS AND DISCUSSION

5.4.1 Summary of producers

See Appendix A for summary of interview results. The farms that were surveyed varied in size from producers having 4 ha to those using 145.7 ha of grazing (mean = 29.8 ha) for grass-fed cattle. Production ranged from 2 grazing animals intended for harvest to 75 cattle harvested (mean= 21.4 head). Most of the producers reported that total farm cattle sales were from grass-fed beef (mean = 86.62 %). Most of the producers reported that cattle sales represent 10-25% of the total farm and non-farm income (mean= 42.3%).

A majority of producers said that their cattle graze forages with grass/legume combinations (mean = 61.1%). The bulk of the grazed hectares are perennial plants (mean = 27.2 ha). Most of the harvested forage is dry hay (mean = 48.3% dry hay). The greater part of the dry hay is stored in a barn (mean = 60.0% in a barn). Producers from this survey used rotational grazing 78.6 % of the time, and used subdivision fencing 28.6 % of the time. The paddock size, in hectares, per animal is relatively constant throughout the season. Producers tended to rotate the cattle through the paddocks more quickly at certain times. Therefore, the frequency of rotations is very variable depending on the season, the number of animals, and the forage quality. Producers may benefit from more portable fencing to rotate the paddocks more often to increase stocking rate and maintain forage quality. Most of the producers have permanent water sources (mean = 60.7%), meaning there is one water source used by all of the animals.
5.4.2 Summary of animals

The predominant breed of cattle was Angus (mean = 29.6 % of cattle) and the other breeds were very variable. The initial weight of the cattle on the farm was extremely variable due to results that indicated some cattle remained on pasture from birth to harvest. Many of the producers are not using preventative vaccines (mean= 48.1 % of the producers) and they did not report major health problems. Some producers reported minor problems with bloat, pink-eye, footrot, and scours. The mean annual health cost per grazed animal was $11.22. The mean length of grazing was 640 d, which is extremely long (min = 343 d; max = 810 d). This could be improved with better genetics and forage maintenance. The mean weight at harvest was 498 kilograms. The mean age at harvest was 21.4 mo with a minimum age of 14 mo and a maximum age of 27 mo. Harvest age may be improved with improved genetics and forage quality.

Local meat processors were used for harvest at a mean distance of 49.6 km from the farm. All the producers used whole carcass aging (mean = 15.3 d) with the exception of one producer who used wet-aging in vacuum packaging. Most of the producers sold retail cuts only (mean = 62.9 % of producers) and used vacuum packaging (mean = 56.8 % of producers). According to the producers, pricing is determined by some combination of production cost, what the market can bear, local competitors, retail prices, and available niche markets. A majority of producers reported advertising by word of mouth was most important (mean score = 8.59 out of a possible 9). Labeling is extremely variable and one producer had a certified organic label because the procedure is “tedious and expensive.” The reasons they produce grass-fed beef for market is because “they like it”, “they do not mind the work”, and the “family time it allows them.” The major production problems reported were “lack of carcass predictability,” “the quality of processors,” and “misinformed consumers and processors.” These features lend
themselves to further research. The results of the survey indicate some specific unrealized production and marketing opportunities for grass-fed beef producers in the Northeast including better genetics, reduced animal age at harvest, and methods to increase carcass predictability.

5.4.3 Summary of economic information

To determine the economic benchmark for these grass-fed beef producers, general questions regarding their finances were asked. Questions included costs for equipment, health, fencing, fertilizers, purchased feeds, and advertising. Producers were also asked about prices for various cuts that they sold. A 2006 financial summary for equipment, health cost, purchased feed, and pasture on a per animal basis was derived. The 2006 financial summary was also calculated for annual cost, net returns to land and labor, and gross income on a whole farm basis.

The summary of farm income and costs associated with grass-fed beef production can be found in Table 5.1. These data indicate the there was a high equipment cost per grazed animal. Health and purchased feed costs per grazed animal were minimal. Pasture costs appear to be minimal because with 150 d of grazing the costs would only be $0.11.d. Comparatively, a typical grain-fed steer in 2006 with a cost of gain of $1.19/kg had a total cost of production of $1,000, which is lower than the reported cost of production of $1,706.02.

5.4.4 Correlations of economic information

Correlations were conducted on net returns to land and labor and gross income with equipment cost, purchased feed cost, land cost, and product value (Table 5.2). Equipment and
purchased feed costs were found to be negatively correlated with net returns to land and labor ($r = -0.42$ and $-0.57$, respectively). The large amount of equipment these producers had and the cost associated with purchased feeds were contributing to higher production costs. Equipment costs can potentially be reduced by using custom operators because pasture mowing and baling hay were the primary uses of equipment. Based on custom rates (Jordan, 2006), mowing and baling for the average surveyed farm was $2,068 and actual average equipment costs exceeded $3,200 per farm (Table 5.1 and Appendix A). Improving the quality of the pastures through intensive rotational grazing may reduce the maintenance and purchased feed cost. Improved pasture management may result in using less hay by stockpiling, improved pasture fertility, and rotational grazing.

Land cost was the singular largest cost associated with these grass-fed beef producers. Reductions in land cost can be achieved with higher production per unit of land or a direct reduction in land cost from rental or relocations.

The length of grazing time was also a major factor in the returns to the producers. Harvest endpoints of animal weight may not insure greater consumer acceptability of the product (Chapter 2), but greater sale weight equates to greater gross income. Therefore, achieving an optimum weight with the least amount of grazing time would be beneficial.

In conclusion, surveys of 26 grass-fed beef producers in the Northeast United States demonstrated that there is a niche market of consumers who demand this product. It has also been shown that reductions in production costs will be necessary to improve net return in these 26 farms. Land and machinery costs are significant contributors to increased costs of production. Greater returns can be achieved through greater product output per farm unit and larger return through enhanced pricing.
### Table 5.1: Summary table of farm income and costs associated with grass-fed beef production

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Equipment</strong></td>
<td>$153.34</td>
<td>$94.08</td>
<td>$7.92</td>
<td>$912.00</td>
</tr>
<tr>
<td><strong>Purchased feed</strong></td>
<td>$7.69</td>
<td>$2.48</td>
<td>$0.24</td>
<td>$62.50</td>
</tr>
<tr>
<td><strong>Health</strong></td>
<td>$11.22</td>
<td>$10.00</td>
<td>$1.00</td>
<td>$35.00</td>
</tr>
<tr>
<td><strong>Advertising</strong></td>
<td>$17.60</td>
<td>$6.00</td>
<td>$0.00</td>
<td>$104.00</td>
</tr>
<tr>
<td><strong>Pasture</strong></td>
<td>$16.63</td>
<td>$6.42</td>
<td>$0.26</td>
<td>$125.02</td>
</tr>
<tr>
<td><strong>Land</strong></td>
<td>$809.85</td>
<td>$452.12</td>
<td>$3.61</td>
<td>$5,000.00</td>
</tr>
<tr>
<td><strong>Winter forage</strong></td>
<td>$78.64</td>
<td>$35.47</td>
<td>$0.73</td>
<td>$328.94</td>
</tr>
<tr>
<td><strong>Mowing</strong></td>
<td>$1.79</td>
<td>$0.60</td>
<td>$0.12</td>
<td>$9.95</td>
</tr>
<tr>
<td><strong>Baling</strong></td>
<td>$1,467.97</td>
<td>$526.50</td>
<td>$90.00</td>
<td>$16,575</td>
</tr>
<tr>
<td><strong>Baling and wrapping</strong></td>
<td>$1,833.92</td>
<td>$833.75</td>
<td>$162.50</td>
<td>$10,625</td>
</tr>
<tr>
<td><strong>Spreading manure</strong></td>
<td>$39.02</td>
<td>$0.72</td>
<td>$0.02</td>
<td>$903.00</td>
</tr>
<tr>
<td><strong>Fertilizer</strong></td>
<td>$75.62</td>
<td>$43.48</td>
<td>$0.13</td>
<td>$290.00</td>
</tr>
<tr>
<td><strong>Annual per animal cost</strong></td>
<td>$1,706.02</td>
<td>$1,306.12</td>
<td>$623.71</td>
<td>$5,907.65</td>
</tr>
<tr>
<td><strong>Gross income</strong></td>
<td>$1,875.54</td>
<td>$1,828.95</td>
<td>$855.00</td>
<td>$3,600</td>
</tr>
<tr>
<td><strong>Net returns to land and labor</strong></td>
<td>$933.88</td>
<td>$960.19</td>
<td>$678.55</td>
<td>$2,392.35</td>
</tr>
<tr>
<td><strong>Age at harvest</strong></td>
<td>640.56</td>
<td>660.00</td>
<td>420.00</td>
<td>810.00</td>
</tr>
</tbody>
</table>

*aCost per steer

*bDays

### Table 5.2: Correlation among farm incomes with costs associated with GFB production

<table>
<thead>
<tr>
<th>Effect</th>
<th>Net Returns to land and labor$^1$</th>
<th>Gross income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment cost</td>
<td>-0.42$^b \pm 0.22$</td>
<td></td>
</tr>
<tr>
<td>Purchased feed cost</td>
<td>-0.57$^c \pm 0.16$</td>
<td>0.34$^d \pm 0.25$</td>
</tr>
<tr>
<td>Land cost</td>
<td>0.58$^e \pm 0.16$</td>
<td>0.63$^f \pm 0.16$</td>
</tr>
</tbody>
</table>

$^1$Numbers in the table are significant partial correlations coefficients ($r$) with their corresponding standard error.

$^aP < 0.1 \hspace{0.5cm} ^bP < 0.05 \hspace{0.5cm} ^cP < 0.01 \hspace{0.5cm} ^dP < 0.001$ P-value are from the correlation procedure.
Reference List


Appendix A

Survey Results

Grass-fed Beef Production In 2006

The term grass-fed beef is here used as a general term for cattle that may include pasture-raised or other generic term for cattle grazed and sold.

1) What is the total ha of the farm being used for beef production?

   a. total hectares of grazing
      Mean: 29.8
      Median: 24
      Minimum: 4.0
      Maximum: 145.7

   b. total hectares of other crops not grazed
      Mean: 16.3
      Median: 6.1
      Minimum: 0
      Maximum: 76.9

   c. total hectares in grass-fed beef intended for slaughter
      Mean: 14.7
      Median: 12
      Minimum: 0.8
      Maximum: 80.9

   d. total hectares in certified organic production
      Mean: 5.2
      Median: 0
      Minimum: 0
      Maximum: 74.9

2) What is the total number of cattle on the farm on July 1, 2006?
   
   • number of cow-calf units
      Mean: 20.15
      Median: 0
      Minimum: 0
      Maximum: 67
The remainder of the questions pertain to grass-fed beef production intended for harvest.

3) Total receipts from the marketing of grass-fed cattle on the farm

- % of the total farm cattle sales from grass-fed beef
  \[ \text{Mean: 86.62} \]
  \[ \text{Median: 100} \]
  \[ \text{Minimum: 10} \]
  \[ \text{Maximum: 100} \]

- Cattle sales represent a) less than 10% of total farm and non-farm income; b) 10%-25% of total farm and non-farm income; c) 25%-50% of total farm and non-farm income; d) 50%-75% of total farm and non-farm income; e) 75%-100% of total farm and non-farm income.
  - 42.3% of the farmers said that cattle sales represent 10-25% of total farm and non-farm income.

4) Forages

- % of hectares grazed by cattle in
  \[ \text{%“native grasses”} \]
  \[ \text{Mean: 20.07} \]
  \[ \text{Median: 0} \]
  \[ \text{Minimum: 0} \]
  \[ \text{Maximum: 100} \]

  % single perennial grass
  \[ \text{Mean: 0} \]
  \[ \text{Median: 0} \]
  \[ \text{Minimum: 0} \]
  \[ \text{Maximum: 0} \]

  % mixed grasses
  \[ \text{Mean: 15.67} \]
  \[ \text{Median: 0} \]
  \[ \text{Minimum: 0} \]
  \[ \text{Maximum: 100} \]
% grass/legume combinations
Mean: 61.07
Median: 75
Minimum: 0
Maximum: 100

% legumes only
Mean: 0.370
Median: 0
Minimum: 0
Maximum: 10

% annual grasses
Mean: 3.04
Median: 0
Minimum: 0
Maximum: 30

% brassicas or forbs
Mean: 1.70
Median: 0
Minimum: 0
Maximum: 20

- Predominant grazed perennial grass is a) orchardgrass; b) smooth bromegrass; c) fescue; d) perennial ryegrass; e) bluegrass; f) other
- 59.3% of the producers reported that the predominant grazed perennial grass was orchardgrass

- Number of grazed hectares by cattle that are annual plants
  Mean: .87
  Median: 0
  Minimum: 0
  Maximum: 10

- Number of grazed hectares by cattle that are perennial plants
  Mean: 27.2
  Median: 20
  Minimum: 0
  Maximum: 145.7
• Number hectares grazed by cattle of intentional forage species mix
  • grass + legume
    Mean: 14.3
    Median: 15
    Minimum: 0
    Maximum: 52.6
  • grass mixture
    Mean: 7.04
    Median: 0
    Minimum: 0
    Maximum: 145.7
  • legume mixture
    Mean: 2.07
    Median: 0
    Minimum: 0
    Maximum: 52.6
  • grass + brassica
    Mean: 1.45
    Median: 0
    Minimum: 0
    Maximum: 19.2
  • other
    Mean: 1.20
    Median: 0
    Minimum: 0
    Maximum: 14.2

• Hectares of predominantly alfalfa pasture grazed by cattle
  Mean: 0.42
  Median: 0
  Minimum: 0
  Maximum: 4.0

5) Harvesting

  a. % of harvested forage as dry hay
    Mean: 48.27
    Median: 44
    Minimum: 0
    Maximum: 100
b. % of harvested forage as balage
   Mean: 36.91
   Median: 25
   Minimum: 0
   Maximum: 100

c. Number of tons of harvested forage as haylage or silage in a tower, bunk, or bag silo
   • % of dry hay stored in a barn
     Mean: 59.94
     Median: 90
     Minimum: 0
     Maximum: 100

   • % of dry hay stored outside
     Mean: 21.54
     Median: 0
     Minimum: 0
     Maximum: 100

   • Number of hectares mowed with no mechanical harvest (bush hogging pasture with possible multiple trips over the same acreage)
     Mean: 18.1 hectares
     Median: 9.3
     Minimum: 0
     Maximum: 101

6) Pasture and Forage Maintenance

   • Fertility applied per acre of grazed forage or total cost of fertilizers for pastures used for beef intended for harvest
     • manure in kilograms
       Mean: $4.4 \times 10^4$
       Median: $1.1 \times 10^4$
       Minimum: 0
       Maximum: $4.5 \times 10^5$

     • dollar cost of spreading manure
       Mean: 39.02
       Median: 0.72
       Minimum: 0.02
       Maximum: 903.00
• Commercial fertilizer dollar cost
  Mean cost: 75.62
  Median: 43.48
  Minimum: 0.13
  Maximum: 290.00

• estimate of kilograms of nitrogen per acre from commercial fertilizer
  Mean nitrogen: 18.96
  Median: 0
  Minimum: 0
  Maximum: 359

• herbicides dollar cost
  Mean cost: 115.33
  Median: 100
  Minimum: 96
  Maximum: 150
  *Four producers said that they used herbicides.*

7) Facilities

• Approximate length, in kilometers, of permanent fencing for pastures used for beef intended for harvest (perimeter and/or interior): <.32 km; 1.609 km; 2.4 km; 3.2 km; 4.0 km; ___ km.
  Mean length: 6.1
  Median length: 3.78
  Minimum: 1.609
  Maximum: 20.1

• What was the initial dollar cost of fencing?
  Mean of initial cost: 13,540
  Median: 10,500
  Minimum: 0
  Maximum: 50,000

• Are these hectares used by animals not beef or beef not intended for harvest? What percentage of the grazing time will other animals use the pasture?
  Mean: 38.40
  Median: 30
  Minimum: 0
  Maximum: 100
• % of grazed hectares by grass-fed beef cattle in subdivision fencing
  Mean: 28.65
  Median: 0
  Minimum: 0
  Maximum: 100

• % of grazed hectares by grass-fed beef cattle in rotational grazing
  Mean: 78.63
  Median: 100
  Minimum: 0.00
  Maximum: 100.00
  Farmers generally kept the paddock size constant throughout the season; they rotated the cattle through the pastures more quickly during lower growth periods.

• usual frequency of rotations (days)
  Mean: 7.88
  Median: 3
  Minimum: 1
  Maximum: 92
  Almost all the producers reported the frequency of rotations was extremely variable. Longer rotations were reported during good forage growth and when the grass is not growing well because of drought they will rotate more quickly.

• Water systems
  • % of water sources in permanent sites (the cattle on the site will all drink from the same water source)
    Mean: 60.74
    Median: 100
    Minimum: 0
    Maximum: 100

  • % of water sources in portable sites (the cattle will drink from a different source in each paddock)
    Mean: 38.89
    Median: 0
    Minimum: 0
    Maximum: 100
• Irrigation dollar cost
  Mean: 3.52
  Median: 2.37
  Minimum: 0.25
  Maximum: 11.58

• cattle handling chutes and corrals
  • approx. age (years)
  Mean age: 15.35
  Minimum age: 0
  Maximum age: 62

8) Equipment
• Tractors: age and current value
  Mean age: 23.7 yr
  Minimum age: .08 yr
  Maximum age: 51 yr

• Hay Mowers/conditioners : age and current value
  Mean of age: 16.8 yr
  Minimum age: 2 yr
  Maximum age: 35 yr

• Hay balers: age and current value
  Mean of age: 20.3 yr
  Minimum age: 1 yr
  Maximum age: 50 yr

• Hay wrappers : age and current value
  Mean of age: 7.3 yr
  Minimum age: 2 yr
  Maximum age: 21 yr

• Rotary mowers: age and current value
  Mean of age: 13.9 yr
  Minimum age: 3 yr
  Maximum age: 30 yr

• Tillage equipment: age and current value
  Mean of age: 15.7 yr
  Minimum age: 2 yr
  Maximum age: 40 yr
• Trucks: % of farm use for cattle, age, and current value
  Mean % of farm use for cattle: 48%
  Minimum % of farm use for cattle: 0
  Maximum % of farm use for cattle: 100
  Mean age: 12.9 yr
  Minimum age: 4 yr
  Maximum age: 29 yr

• Stock trailers: % of farm use for cattle, age, and current value
  Mean % of farm use for cattle: 81%
  Minimum % of farm use for cattle: 0
  Maximum % of farm use for cattle: 50
  Mean of age: 9.1 yr
  Minimum age: 2 yr
  Maximum age: 20 yrs

• Other equipment: age and current value
  Mean age: 11.0 yr
  Minimum age: 2 yrs
  Maximum age: 30 yrs

• Total equipment dollar cost
  Mean: 153.44
  Median: 94.08
  Minimum: 7.92
  Maximum: 912.00

9) Cattle

• # of head and % of total grass-fed beef cattle intended for harvest raised on the farm
  Mean: 16
  Median: 8
  Minimum: 0
  Maximum: 75
  Mean: 61.73
  Minimum: 0
  Maximum: 100
• # of head and % of cattle purchased for resale as grass-fed beef intended for harvest
  Mean: 6.63
  Median: 2
  Minimum: 0
  Maximum: 42
  Mean %: 38.27
  Minimum %: 0
  Maximum %: 100

• Predominant breed of cattle
  ▪ Angus: 29.63%
  ▪ Angus Scottish Highland: 3.70%
  ▪ Hereford: 22.22%
  ▪ Limousin: 7.40%
  ▪ Devon: 7.40%
  ▪ Red angus: 3.70%
  ▪ American Lowline: 3.70%
  ▪ Galloway-British White Cross: 3.70%
  ▪ Scottish Highland: 11.11%
  ▪ Mixed Commercial Cattle: 3.70%
  ▪ Highland: 3.70%

• Initial kilograms of cattle grazed and intended for harvest (at turnout)
  Mean: 257.8
  Median: 249
  Minimum: 34
  Maximum: 521.6

  The reason for this large range is because some producers reported those raised on the farm were placed on pasture at calving.

• Health program
  • IBR, BVD, PI3, BRSV, H. somnus, other respiratory vaccines used
    • 48.1% of the producers surveyed are not vaccinating
  • Deworming cost
    Mean cost: $5.31
    Median: 3.45
    Minimum cost: 0
    Maximum cost: 10
• Primary health concerns:
  • bloat
  • respiratory disease
  • scours
  • coccidiosis
  • grass tetany
  • SE deficiencies
  • Footrot
  • Others
  • *Most of the producers reported that health was not a major concern.*
  • *Some that were noted: bloat, pinkeye, footroot, and scours*

• annual health dollar cost per grazed animal intended as beef
  Mean: 11.22
  Median: 10.00
  Minimum: 1.00
  Maximum: 35.00

• % heifers, % steers, % bulls grazed for harvest
  • *No bulls were grazed for harvest; heifer numbers fluctuated due to the need for replacement females.*

• Implants used (yes, no)
  • *No implants were used*

• Purchased feeds: dollar cost
  Mean: 7.69
  Median: 2.48
  Minimum: 0.24
  Maximum: 62.50

• Wintering programs (non-forage growth phase—usually November through April)
  • dry hay dollar cost
    Mean: 40.04
    Median: 18.90
    Minimum: 0.73
    Maximum: 180.00
  • balage dollar cost
    Mean: 70.81
    Median: 50.27
    Minimum: 0.54
    Maximum: 265.78
• grazing stockpiled forage (the number of days cattle intended for harvest graze with no other feed available from November through April
  Mean: 46.31
  Median: 17.5
  Minimum: 0
  Maximum: 214

• Haylage or silage kilograms
  Mean: 1.8 x10⁴
  Median: 0
  Minimum: 0
  Maximum: 2.27 x10⁵

• grains
  • corn % used
    Mean: 10.96
    Median: 0
    Minimum: 0
    Maximum: 100

  • byproducts % used
    Mean: 0
    Median: 0
    Minimum: 0
    Maximum: 0

  • small grains % used
    Mean: 1.92
    Median: 0
    Minimum: 0
    Maximum: 50

  • commercial feeds % used
    Mean: 7.69
    Median: 0
    Minimum: 0
    Maximum: 100
• % of cattle raised from AI mating
  Mean: 9.24
  Median: 0
  Minimum: 0
  Maximum: 100
  *Six producers used AI mating*

• Major selection tools used for production of cattle grazed for harvest as beef
  • What is the most important selection tool?
    • *Most producers reported that breed and frame size were most important.*
    • *Other reported an expected balance of traits.*

• Average number of *days* cattle graze between weaning and harvest
  • shortest expected grazing period
    Mean: 289.44
    Median: 270
    Minimum: 0.00
    Maximum: 730
  • longest expected grazing period
    Mean: 397.22
    Median: 360
    Minimum: 90
    Maximum: 870
  • *Implies that the producers are wintering cattle twice*
  • *There is a substantial cost added to production*
  • *Genetics may be a good tool to speed up production*

10) Cattle Harvest

• the major factor determining harvest date: a) animal weight b) animal age; c) fat thickness; d) days grazed; e) available processor; f) calendar date; g) other
  • *Fat thickness with 37% of the producers*
  • *Very variable*

• average live weight *kilograms* at harvest and weight range
  Mean: 498
  Median: 499
  Minimum: 318
  Maximum: 680
• average age at harvest and age range in days
  Mean of average age at harvest: 640.56
  Median: 660
  Minimum age: 420
  Maximum: age: 810
  • *A reflection of grazing period: some cost reductions may be needed.*

• Numbr cattle harvested at each harvest date and range
  Mean: 4.3
  Median: 3
  Minimum: 1
  Maximum: 20

11) Processing
• Distance *(kilometers)* to processor
  Mean: 49.6
  Median: 40
  Minimum: 5
  Maximum: 161

• transportation time *(minutes)* to processor
  Mean: 46.39
  Median: 40
  Minimum: 5
  Maximum: 90

• average time *(hours)* interval between farm loadout and knockdown
  Mean: 12.52
  Median: 12
  Minimum: 0
  Maximum: 45

• number of processors available to use within a 100-mile radius
  Mean: 33.92
  Median: 4.5
  Minimum: 1
  Maximum: 500

• carcass aging
  • average length of time *(days)* of aging
    Mean: 15.35
    Median: 14
    Minimum: 1.5
    Maximum: 30
• % whole carcass aging
  Mean: 100
  Minimum: 100
  Maximum: 100

• % wet aging in vacuum packaging
  Mean: 3.70
  Median: 0
  Minimum: 0
  Maximum: 100
  * Only one producer did wet aging in vacuum packaging

• who determines aging time
  * producer
  * processor
  * customer
  * Aging time is usually determined by the producer

• fabrication of carcass
  • % wholesale cuts only (whole chuck, rib, loin or round)
    Mean: 25.54
    Median: 0
    Minimum: 0
    Maximum: 100

  • % retail cuts only
    Mean: 62.92
    Median: 100
    Minimum: 0
    Maximum: 100

  • % mix of wholesale and retail cuts
    Mean: 7.69
    Median: 0
    Minimum: 0
    Maximum: 100

• Is the product frozen or fresh at pickup from the processor
  • Almost all of the producers’ products were frozen at pick-up from the process.
  • Only one producer’s products were fresh at pick-up from the processor
• Is the product frozen or fresh at the point of sale
  • *Almost all of the producers’ products were frozen at point of sale*
  • *Only three producers’ products were fresh at point of sale*

• who determines cutting process
  • processor
  • customer
  • producer
  • *The cutting process is generally determined by the processor and customer*

• type of packaging
  • % freezer wrap
    Mean: 39.30
    Median: 1
    Minimum: 0
    Maximum: 100
  
  • % vacuum package
    Mean: 56.78
    Median: 60
    Minimum: 0
    Maximum: 100
  
  • % retail case visual packaging
    Mean: 0
    Median: 0
    Minimum: 0
    Maximum: 0
  
  • % modified atmospheric packaging
    Mean: 0
    Median: 0
    Minimum: 0
    Maximum: 0

• process interventions
  • electro-stimulation
  • *No one used this and the majority of the producers did not know what it was*
• % of carcasses graded for USDA quality grades
  Mean: 14.11
  Median: 0
  Minimum: 0
  Maximum: 100

• Five producers had their carcasses graded

• % of carcasses with fat profile analysis
  Mean: 3.93
  Median: 0
  Minimum: 0
  Maximum: 100

• Three producers used the fat profile analysis

• feeding carcass enhancements such as Vitamin E

• No producers used carcass enhancements

12) Marketing
  • pricing
    • % sold by the kg on live weight and mean price (dollar/kg)
      Mean: 8.59
      Median: 0
      Minimum: 0
      Maximum: 100

      Mean $/kg: 4.72
      Median: 2.65
      Minimum: 2.56
      Maximum: 11.02

    • % sold by the kg on hot carcass weight and mean price (dollar/kg)
      Mean: 55.33
      Median: 70
      Minimum: 0
      Maximum: 100

      Mean $/kg: 5.56
      Median: 5.18
      Minimum: 3.53
      Maximum: 9.37

    • % sold as individual retail cuts and mean price (dollar/kg)
      Mean: 24.59
      Median: 0
      Minimum: 0
      Maximum: 100
Mean ($/kg): 14.09
Median: 13.23
Minimum: 7.72
Maximum: 34.73

- % sold as package of cuts and mean price (dollar/kg)
  Mean: 7.78
  Median: 0
  Minimum: 0
  Maximum: 100

  Mean ($/kg): 13.69
  Median: 12.68
  Minimum: 4.96
  Maximum: 27.56

- Most important price determination
  - local markets for live cattle
  - “yellow sheet” or national fat steer market
  - cost plus % added value
  - other

  - What it costs to produce
  - What market can bear
  - Local competitors
  - Retail prices
  - Niche Market

- advertisement: score importance from 1 to 9 with 9 being highly important and 1= not important at all or not used
  - word of mouth
    Mean: 8.59
    Median: 9
    Minimum Score: 4
    Maximum Score: 9

  - printed fliers are distributed and dollar cost
    Mean: 3.78
    Median: 3
    Minimum: 1
    Maximum: 9
    Mean $/yr: 4.82
    Median: 3.13
    Minimum: 0
    Maximum: 25
• newspaper and magazine ads and dollar cost
  Mean: 2.26  
  Median: 1  
  Minimum: 1  
  Maximum: 9  
  Mean $/yr: 20.52  
  Median: 13.33  
  Minimum: 1.50  
  Maximum: 75

• web site and dollar cost
  Mean: 2.54  
  Median: 1  
  Minimum: 1  
  Maximum: 8.50  
  Mean $/yr: 19.44  
  Median: 3.13  
  Minimum: 0  
  Maximum: 101.87

• Farm tour and dollar cost
  Mean: 1.58  
  Median: 1  
  Minimum: 1  
  Maximum: 7  
  Mean $/yr: 6.25  
  Median: 0  
  Minimum: 0  
  Maximum: 18.75

• Presentation and dollar cost
  Mean: 1.26  
  Median: 1  
  Minimum: 1  
  Maximum: 5  
  Mean $/yr: 1.94  
  Median: 1.94  
  Minimum: 1.94  
  Maximum: 1.94

  One producer did presentations.
• Mailing and dollar cost
  Mean: 1.30
  Median: 1
  Minimum: 1
  Maximum: 9
  Mean $/yr: 33.33
  Median: 33.33
  Minimum: 33.33
  Maximum: 33.33
  *One person did mailing.*

• Membership and dollar cost
  Mean: 1.30
  Median: 1
  Minimum: 1
  Maximum: 9
  Mean $/yr: 3.13
  Median: 3.13
  Minimum: 2.50
  Maximum: 3.75

• customer source
  • % freezer beef
    Mean: 71.56
    Median: 100
    Minimum: 0
    Maximum: 100

  • % conventional markets and sale barns
    Mean: 0.56
    Median: 0
    Minimum: 0
    Maximum: 10

  • % farmer-owned retail outlet
    Mean: 9.96
    Median: 0
    Minimum: 0
    Maximum: 80

  • % non-owned retail outlet (grocery store, etc.)
    Mean: 1.11
    Median: 0
    Minimum: 0
    Maximum: 30
• % restaurants
  Mean: 7.93
  Median: 0
  Minimum: 0
  Maximum: 100

• % mail order
  Mean: 0.07
  Median: 0
  Minimum: 0
  Maximum: 2

• % cooperative and multi-farmer group sales
  Mean: 8.81
  Median: 0
  Minimum: 0
  Maximum: 90
  - Majority of the producers have freezer beef
  - Six producers have a store
  - One producer is doing mail order
  - Fewer producers are marketing to sale barns, grocery stores and restaurants

• packaging
  • % farm label used
    Mean: 21.41
    Median: 0
    Minimum: 0
    Maximum: 100

  • % USDA process verified label used
    Mean: 46.41
    Median: 27
    Minimum: 0
    Maximum: 100

  • % BQA or process label used
    Mean: 8.15
    Median: 0
    Minimum: 0
    Maximum: 100
• % natural label used
  Mean: 3.70
  Median: 0
  Minimum: 0
  Maximum: 100

• % certified organic label used
  Mean: 0.93
  Median: 0
  Minimum: 0
  Maximum: 25

• % No labeling used
  Mean: 13.81
  Median: 0
  Minimum: 0
  Maximum: 100

• % Other label used and name
  Mean: 66.59
  Median: 100
  Minimum: 0
  Maximum: 100
  • 83.3% of “other” labels were Cut ID

13) Producer information

• average age (yr) of the manager(s) of the grass-fed production farm
  Mean: 48.3
  Median: 50
  Minimum: 25
  Maximum: 74

• female or male
  • 70% male
  • 25% were included male and female
  • Only one female

• Education (%)
  • less than high school
    7.41
  • high school graduate
    14.81
  • college or technical school graduate
    29.63
• professional or graduate school
  48.15

• Raised on a farm (yes, no)
  • 59.26% of the producers were raised on the farm

• Number of years producing and marketing grass-fed beef for harvest
  Mean: 10.67
  Median: 6
  Minimum: 1
  Maximum: 103

• Business debt for assets dedicated to grass-fed beef for harvest
  Debt (dollar) on cattle
  Mean: 1,777.78
  Median: 0.00
  Minimum: 0.00
  Maximum: 20,000.00

  Debt (dollar) on equipment
  Mean: 6,703.70
  Median: 0.00
  Minimum: 0.00
  Maximum: 100,000.00

  Debt (dollar) on land
  Mean: 34,629.63
  Median: 0.00
  Minimum: 0.00
  Maximum: 225,000.00

• Estimated asset value of farm attributed to grass-fed beef cattle operation
  (what could the farm be sold for today?)
  Mean: 733,825.93
  Median: 500,000.00
  Minimum: 0.00
  Maximum: 4,000,000.00

• Annual dollar cost of hired labor
  Mean: 9,609.29
  Median: 1,500.00
  Minimum: 200.00
  Maximum: 40,000.00
• % of annual work from hired labor
  
  **Mean:** 13.06  
  **Median:** 1  
  **Minimum:** 0  
  **Maximum:** 80

• Average number of **hours** per day dedicated to grass-fed beef production by manager and/or hired labor.
  
  **Mean:** 3.06  
  **Median:** 2.25  
  **Minimum:** 0.1667  
  **Maximum:** 8

Please **score** the following items 1-9 you perceive as the reasons you produce grass-fed beef for sale with 9= very important reason and 1=not important at all to me:

a. life-style
  
  **Mean:** 7.33  
  **Median:** 8  
  **Minimum:** 1  
  **Maximum:** 9

b. profit
  
  **Mean:** 6.33  
  **Median:** 6  
  **Minimum:** 1  
  **Maximum:** 9

c. environmental concerns
  
  **Mean:** 7.13  
  **Median:** 9  
  **Minimum:** 1  
  **Maximum:** 9

d. human health issues
  
  **Mean:** 7.56  
  **Median:** 9  
  **Minimum:** 1  
  **Maximum:** 9

e. animal welfare concerns
  
  **Mean:** 7.35  
  **Median:** 8  
  **Minimum:** 1  
  **Maximum:** 9

f. available markets
  
  **Mean:** 6.96  
  **Median:** 7  
  **Minimum:** 1  
  **Maximum:** 9
g. labor available
   Mean: 3.93
   Median: 3
   Minimum: 1
   Maximum: 9

h. facilities and equipment available
   Mean: 5.04
   Median: 5
   Minimum: 1
   Maximum: 9

i. vegetative control on the farm
   Mean: 5.37
   Median: 6
   Minimum: 1
   Maximum: 9

j. as part of a crop rotation
   Mean: 3.26
   Median: 2
   Minimum: 1
   Maximum: 9

k. other (name)
   • Money
   • Workaholic

Please rank the following you perceive as problems you encounter in producing and marketing grass-fed beef with 9= very important problem and 1=not important at all to me:

a. life-style change
   Mean: 1.93
   Median: 1
   Minimum: 1
   Maximum: 9

b. identification of new customers
   Mean: 4.11
   Median: 4
   Minimum: 1
   Maximum: 9

c. lack of cattle production information
   Mean: 2.78
   Median: 2
   Minimum: 1
   Maximum: 5

d. availability of processors
Mean: 4.81
Median: 4
Minimum: 1
Maximum: 9
e. animal health
   Mean: 2.63
   Median: 2
   Minimum: 1
   Maximum: 9
f. consistency of meat products
   Mean: 4.78
   Median: 5
   Minimum: 1
   Maximum: 9
g. labeling and packaging issues
   Mean: 3.19
   Median: 2
   Minimum: 1
   Maximum: 7
h. time commitment for selling and promoting products
   Mean: 4.78
   Median: 5
   Minimum: 1
   Maximum: 9
i. availability of cattle
   Mean: 4.11
   Median: 3
   Minimum: 1
   Maximum: 9
j. lack of forage production information
   Mean: 2.52
   Median: 2
   Minimum: 1
   Maximum: 9
k. returns from customers/critical customers
   Mean: 2.19
   Median: 2
   Minimum: 1
   Maximum: 9
l. marketing the whole carcass
   Mean: 3.00
   Median: 2
   Minimum: 1
   Maximum: 9
m. identification of market outlets
Mean: 4.52
Median: 5
Minimum: 1
Maximum: 9

n. lack of capital
Mean: 3.37
Median: 2
Minimum: 1
Maximum: 9

o. other and name

- Predictability
- Procedure for becoming organic
- Quality of processors
- Getting water sources in every paddock
- Marginal rate of return on investment
- Marketing to new customers
- Misinformed consumers and producers
- Lack of information about proper procedure for storing forage over winter months
- Getting satisfactory returns in the shortest amount of time (genetics)