51st International Congress of Meat Science and Technology
August 7-12, 2005 – Baltimore, Maryland USA

TENDERNESS AND COLLAGEN CHARACTERISTICS OF STEERS FINISHED AS CALVES OR YEARLINGS

P.S. Brewer, J.M. James*, C.R. Calkins, R.J. Rasby, T.J. Klopfenstein, and R.V. Anderson

Department of Animal Science, University of Nebraska, Lincoln, NE

Key Words: Beef, Finishing, Management Systems, Tenderness, Collagen

Introduction

Lack of consistency is one of the biggest concerns for today's beef industry. Inadequate tenderness and lack of uniformity in cattle ranked first and second, respectively, as the greatest challenges for all sectors of beef production (Smith, Savell, Morgan, & Montgomery, 2000). The National Beef Quality Audit stated that lack of uniformity in cattle is the concern for purveyors, restaurateurs, and retailers, which has shown the least improvement of the tracked concerns since 1991. Animal management plays a key role in the quality of the final end product. Calf finishing systems in the U. S. use large amounts of grain to feed high concentrate diets to weanlings for extended periods of time. In contrast, yearling systems are more extensive, growing calves for a longer period of time on forage before being fed a high concentrate diet for a short period prior to harvest. This reduction of days on a high concentrate diet may reduce costs; however, decreased days on feed have been associated with lower quality grades and less tender beef (Miller, Cross, Crouse, & Tatum, 1987; May, Dolezal, Gill, Ray, & Buchanan, 1992). Regardless of the management practice used to increase profitability, cattle produced must be of the type that are acceptable for the feedlot and yield a final product desirable to the consumer.

Literature provides varied results when comparing meat quality from finished calves and yearlings. Calves have been reported to produce carcasses with increased fat thickness, higher numerical yield grades and quality grades (Lunt and Orme, 1987), and more tender meat (Dikeman, et al., 1985; Johnson, Huffman, Williams, & Hargrove, 1990). However, others have shown minimal effects on carcass quality grade or meat palatability (Dikeman, Dayton, Hunt, Kastner, Axe, & Ilg, 1985; Huffman, Williams, Hargrove, Johnson, & Marshall, 1990).

Collagen solubility decreases (Hill, 1966; Cross, Carpenter, & Smith, 1973) and collagen cross-linkages increase (Goll, Bray, & Hoekstra, 1964; Goll, Hoesktra, & Bray, 1964; Cross, et al., 1973) in muscle as physiological age increases. Miller, Cross, Crouse, & Jenkins (1987) found decreased insoluble collagen and a higher percentage of newly synthesized soluble collagen in mature cows that had received a high energy diet prior to slaughter. This led to lower Warner-Bratzler shear force values and higher sensory tenderness scores compared to mature cows on a low-energy diet.

Objectives

Therefore, this study was conducted over a two year span to determine if collagen characteristics were responsible for tenderness differences of steers produced in the calf-fed and yearling systems when fed to a constant fat thickness.

Methodology

Steers (3/4 British, 1/4 Continental) were randomly assigned to be finished as calves (CF) or yearlings (YF) at weaning. Thirty-five and 41 calves and 42 and 41 yearlings were designated in year 1 and year 2, respectively.

Each year at weaning, CF steers were implanted (Synovex-S©) and were adapted from a 50% concentrate diet to a 92.5% concentrate finishing diet (TDN 84%, CP 12%) fed until harvest. Reimplantation (Revalor-S©) occurred after 90 d on feed. All steers were fed to an estimated 12th-rib fat thickness endpoint of 1 cm. To achieve this, Year 1 steers were on feed for 203 d and Year 2 steers were fed for 180 d. The CF steers were approximately 13 to 14 months old at the time of harvest.

The YF steers were drylotted for 60 d, until corn stalks became available for grazing. While in drylot, these steers were fed ammoniated wheat straw ad libitum and supplemented with mineral and 2.27 kg/head/d (DM basis) of wet corn gluten feed. Steers then grazed corn stalks for 78 d in Year 1 and 91 d in Year 2. Hay was supplemented during heavy snow cover. After grazing corn stalks, steers were again drylotted for the remainder of the wintering period until pasture was available for spring and summer grazing. Spring drylot was 64 d in Year 1 and 50 d in Year 2. Following the spring drylotting period, steers grazed pastures for 96 d in Year 1 and 103 days in Year 2. Steers were implanted (Revalor-G©) prior to summer grazing. Spring grazing pastures consisted of smooth bromegrass. Summer grazing pastures consisted of big bluestem, indiangrass, and switchgrass. Following the summer grazing period, steers entered the feedlot, were reimplanted (Revalor-S©), blocked by weight, and assigned randomly to one of two pens. Steers were then fed similarly to the CF for receiving and finishing periods. This final finishing period consisted of 93 d in Year 1 and 90 d in Year 2. The YF steers were approximately 19 to 20 months old at the time of harvest.

Steers were harvested in a commercial slaughter facility. Shortly after being bled, carcasses were electrically stimulated with 8 to 10 low voltage (40 V) pulses. Hot carcass weights were obtained from all steers at the time of slaughter. In Year 1, carcasses were chilled for an extended 48 hour weekend chill period. Carcasses in Year 2 were chilled for approximately 42 hours. A marbling score was assigned to the carcass by the USDA grader. Other carcass data were measured and evaluated by experienced University of Nebraska personnel. Carcass measurements were used to calculate yield and quality grades. A boneless beef strip loin (IMPS #180) was collected from the left side of each carcass. Two strip loins from CF cattle were lost during the fabrication process, so additional data analysis continued on 34 and 40 strip loins in Year 1 and Year 2, respectively.

At 7 d postmortem, strip loins were cut into 2.54 cm *M. longissimus dorsi et lumborum* steaks for proximate analysis, Warner-Bratzler shear force (WBS) and sensory panel evaluation. Individual steaks were designated for aging time (7, 14, and 21 d), shear force, and sensory evaluations, wrapped, and frozen at -22 °C until further analyses.

Frozen steaks were thawed at 4 °C for 24 h prior to cooking. Steaks were cooked to an internal temperature of 70 °C (AMSA, 1995) on a Farberware Open-Hearth broiler (Model 455N, Walter Kidde and Co., Bronx, NY). After cooling, 8 to 10 cores (1.27 cm in diameter) were removed and sheared using a Warner-Bratzler shear attachment to an Instron Universal testing machine (Model 55R1123, Canton, MA). The mean peak shear force (kg) of at least 6 cores was calculated for each steak.

Samples from the CF and YF steers were analyzed for soluble, insoluble, and total collagen according to Hill (1966) and Cross, et al., (1973). Soluble collagen was calculated with a 7.52 constant, and insoluble was calculated with a 7.25 constant (Goll, Bray, & Huekstra, 1963).

Steaks for sensory evaluation were cooked by the same procedure as described for WBS. After cooking the steaks were cut into 1 x 2 x 1 cm pieces for evaluation. Samples were served to a consumer sensory panel ($n \geq 30$) in individual booths under red lighting to mask differences in meat color. An 8-point Hedonic scale (8 = extremely desirable; 1 = extremely undesirable) was used to evaluate tenderness, juiciness, flavor, and overall acceptability.

Carcass traits, chemical characteristics, WBS, and consumer sensory panel data were analyzed using GLM procedure of SAS (1999). Both years were pooled and each steer was an experimental unit for carcass traits and chemical characteristics. Steaks at each aging time were experimental units for shear force and sensory evaluations.

Results & Discussion

Carcass characteristics for CF and YF steers are summarized in Table 1. The YF steers yielded heavier ($P<0.01$) carcass weights with larger ($P<0.01$) longissimus muscle areas, and less ($P<0.01$) internal fat. They also had lower ($P<0.01$) marbling scores, USDA quality grades, and percentage of carcasses grading USDA Choice or higher when compared to carcasses of CF steers. The differences in marbling scores were confirmed with chemical analysis (8.5 versus 5.5% fat).

As expected, increased aging time from 7 to 14 to 21 d produced steaks with lower ($P<0.05$) shear force values, regardless of production system (Table 2). Steaks from CF had lower ($P<0.01$) shear force values at 7, 14, and 21 d of age (Table 2) than steaks from yearlings. The YF steers had steaks that, after aging 21 d, had similar shear force values to CF steaks aged 7 d. They were also rated higher ($P<0.05$) for tenderness, as well as juiciness, flavor, and overall acceptability (Table 3) after 7 and 14 days of aging. This was also true when comparing all Choice steaks or all Select steaks ($P<0.05$).

The lower WBS values and higher sensory tenderness scores may be attributed to the collagen differences in the two groups. The CF had a more insoluble ($P<0.01$), soluble ($P<0.01$), and total collagen ($P<0.01$) than the yearlings (Table 4). The higher total and insoluble values are probably due to dilution of collagen by muscle fiber growth. However, the collagen from the CF steers was much more soluble ($P<0.01$) than from the YF steers (39.7 versus 24.4%, respectively). Hill (1966) demonstrated that collagen solubility decreases in muscle as physiological age increases. Solubility of collagen has been shown to be positively correlated to textural characteristics (Goll, et al., 1963).

Miller, Tatum, Cross, Bowling, and Clayton (1983) did not find these results. However, Aberle, Reeves, Judge, Hunsley, and Perry (1981) hypothesized that beef cattle feed high concentrate diets would have higher protein turnover and thus greater collagen solubility that would allow for less cross-linkages and more tender beef. The CF steers were on a high concentrate diet for a longer period of time which supports that rationale.

Conclusions

Growing steers for a longer period of time on forage with a short finishing period resulted in heavier carcasses with lower quality grades and beef that was less tender than CF steers. Steers finished as calves spent more days in the feedlot and in this study produced beef that was more tender and possessed more acceptable eating characteristics than yearlings. Collagen differences, especially soluble collagen amounts, may help explain the lower shear force values and higher tenderness ratings for the CF steers.

Table 1. Comparison of means for carcass characteristics from calf- and yearling-finished steers.

	Calves		Yearlings		
Trait	Mean	SE	Mean	SE	*P*-value
Hot carcass weight, kg	315.4[b]	3.37	375.9[c]	3.18	<0.0001
Fat thickness, cm	1.39	0.045	1.30	0.042	0.1880
Adjusted fat thickness, cm	1.50	0.039	1.42	0.037	0.1479
Longissimus muscle area, cm^2	72.76[b]	0.67	81.06[c]	0.63	<0.0001
Kidney, pelvic, heart fat, %	2.33c	0.053	2.07[b]	0.050	0.0004
Yield grade	3.49	0.054	3.46	0.050	0.6423
Marbling scorea	454.1[c]	8.80	346.1[b]	8.28	<0.0001

[a]Marbling score: modest = 500-599; small = 400-499; slight = 300-399.
[bc]Means in the same row without a common superscript are different (*P*<0.01).

Table 2. Mean shear force values for steaks aged 7, 14, and 21 days from calf- and yearlingfinished steers.

	Calves		Yearlings		
Age, d	Mean	SE	Mean	SE	*P*-value
7	3.30[b,c]	0.089	4.09[e]	0.109	<0.0001
14	3.07[b]	0.089	3.74[d]	0.109	<0.0001
21	2.79[a]	0.089	3.40[c]	0.109	<0.0001

[abcde]Means without common superscripts are different (*P*<0.05).

Table 3. Mean sensory panel ratings for steaks aged 7 or 14 days from calf- or yearling-finished steers.

		Calves		Yearlings	
Age, d	Trait[z]	Mean	SEM	Mean	SEM
7	Juiciness	5.08[d]	0.032	4.88[e]	0.039
	Tenderness	5.46[a]	0.034	4.56[c]	0.043
	Flavor	4.96[d]	0.033	4.64[e]	0.041

	Overall Acceptability	5.07[d]	0.032	4.47[e]	0.039
14	Juiciness	4.86[e]	0.032	4.61[f]	0.039
	Tenderness	5.59[b]	0.034	4.63[c]	0.043
	Flavor	4.99[d]	0.033	4.70[e]	0.041
	Overall Acceptability	5.03[d]	0.032	4.49[e]	0.039

[abc]Means for a given trait without a common superscript are different ($P < 0.05$).
[def]Means for a given trait without a common superscript are different ($P < 0.01$).
[z]Consumer panel rating for each trait: 8=extremely desirable; 1=extremely undesirable.

Table 4. Collagen (mg/g) in the longissimus muscle of calf- or yearling-finished steers.

	Calves		Yearlings		
Collagen	Mean	SE	Mean	SE	*P*-value
Insoluble	8.11[a]	0.391	6.19[b]	0.357	0.0004
Soluble	6.23[a]	0.408	2.21[b]	0.372	<0.0001
Total	14.52[a]	0.742	8.46[b]	0.678	<0.0001
% Soluble	39.72[a]	2.528	24.38[b]	2.308	<0.0001

[ab]Means in the same row without common superscript are different (P < 0.01).

References

Aberle, E.D., Reeves, E.S., Judge, M.D., Hunsley, R.E. & Perry, T.W. (1981). Palatability and muscle characteristics of cattle with controlled weight gain: time on a high energy diet. Journal of Animal Science 52(4):757–763.

AMSA. 1995. Research Guidelines for Cookery, Sensory Evaluation, and Instrumental Tenderness Measurements fo Fresh Meat. Amer. Meat Sci. Assoc., Chicago, IL.

Cross, H.R., Carpenter, Z.L., & Smith, G.C. 1973. Effects of intramuscular collagen and elastin on bovine muscle tenderness. Journal of Food Science 38:998–1003.

Dikeman, M.E., Dayton, A.D., Hunt, M.C., Kastner, C.L., Axe, J.B., & Ilg, H.J. (1985) Conventional versus accelerated beef production with carcass electrical stimulation. Journal of Animal Science 61:573–583.

Dikeman, M.E., Nagele, K.N., Myers, S.M., Schalles, R.R., Kropf, D.H., Kastner, C.L., & Russo, F.A. (1985) Accelerated versus conventional beef production and processing. Journal of Animal Science 61:137–150.

Goll, D.E., Bray, R.W., & Huekstra, W.G. (1963) Age associated changes in muscle composition. The isolation and properties of collagenous residue from bovine muscle. Journal of Food Science 28:503–509.

Goll, D.E., Bray, R.W., & Huekstra, W.G. (1964) Age associated changes in bovine muscle connective tissue. III. Rate of solubilzation at 100°C. Journal of Food Science 29:622–628.

Goll, D.E., Huekstra, W.G., & Bray, R.W. (1964) Age associated changes in bovine muscle connective tissue. II. Exposure to increasing temperature. Journal of Food Science 29: 615–621.

Hill, F. (1966) The solubility of intramuscular collagen in meat animals of various ages. Journal of Food Science 31(2):161–166.

Huffman, R.D., Williams, S.E., Hargrove, S.E., Johnson, D.D., & Marshall, T.T. (1990) Effects of percentage Brahman and Angus breeding, age-season of feeding and slaughter end point on feedlot performance and carcass characteristics. Journal of Animal Science 68:2243–2252.

Johnson, D.D., Huffman, R.D., Williams, S.E., & Hargrove, D.D. (1990) Effects of percentage Brahman and Angus breeding, age-season of feeding and slaughter end point on meat palatability and muscle characteristics. Journal of Animal Science 68:1980–1986.

Lunt, D. K. & Orme, L.E. (1987) Feedlot performance and carcass evaluation of heifers fed finishing diets as weanling calves or as yearlings. Meat Science. 20:159–164.

May, S.G., Dolezal, H.G., Gill, D.R., Ray, F.K., & Buchanan, D.S. (1992) Effects of days fed, carcass grade traits, and subcutaneous fat removal on postmortem muscle characteristics and beef palatability. Journal of Animal Science. 70:444–453.

Miller, R.K., Cross, H.R., Crouse, J.B., & Jenkins, T.G. (1987) Effect of feed energy intake on collagen characteristics and muscle quality of mature cows. Meat Science. 21:287–294.

Miller, R.K., Tatum, J.D., Cross, H.R., Bowling, R.A., & Clayton, P. (1983) Effects of carcass maturity on collagen solubility and palatability of beef from grain finished steers. Journal of Food Science 48:484–486, 525.

SAS. 1999. SAS/STAT Users Guide (Version 8.0). SAS Institute Inc. Cary, NC.

Smith, G.C., Savell, J.W., Morgan, J.B., & Montgomery, T.H. (2000) Improving the quality consistency, competitiveness, and market share of fed beef. The Final Report of the Third Blueprint for Total Quality Management in the Fed-Beef (Slaughter Steer/Heifer) Industry: National Beef Quality Audit-2001. National Cattlemen’s Beef Association, Englewood, CO