EFFECTS OF TIME-ON-FEED ON CARCASS GRADE TRAITS, POSTMORTEM MUSCLE CHARACTERISTICS AND BEEF PALATABILITY

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Story in Brief

Forty-eight Angus x Hereford steers with similar frame size and muscle thickness were fed a high concentrate diet and serially slaughtered at 28-day intervals over a 196-day finishing period, except for the 0-day group which served as a grass-fed control. Upon slaughter, a randomly selected side of each carcass was trimmed of subcutaneous fat in the wholesale rib region. Postmortem ribeye temperature was monitored for each side over a 24 hour chilling period. Following quality and yield grade data collection, rib steaks were removed, aged for seven days and sensory traits were evaluated. Most carcass grade traits increased linearly while most sensory panel variables and marbling increased curvilinearly with increased days-fed. As time-on-feed increased from 0 to 84 days, tenderness improved ; however, once steers were fed a minimum of 84 days there was little improvement in tenderness. Postmortem muscle temperature at 2.5 hours was the variable most highly correlated with tenderness. Simple correlation coefficients for shear force with 2.5-hour ribeye temperature, marbling score, days-fed, fat thickness and carcass weight were -.63, -.61 -.56, -.55 and -.53, respectively. Sides trimmed of subcutaneous fat chilled more rapidly, had lower 2.5-hour ribeye temperatures, shorter sarcomeres and lower sensory tenderness ratings than untrimmed sides. Path coefficient analysis revealed that ribeye temperature at 2.5 hours accounts for the most variation in shear force values.

(Key Words: Carcass Traits, Postmortem Temperature, Time-on-feed, Palatability.)

Introduction

Due to an expanding health conscious society, current consumer trends have shifted toward the consumption of leaner beef products. However, at

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the same time, a certain segment of the population does not desire to sacrifice eating quality (Savell et al., 1987). Therefore, the ability to accurately predict beef palatability is of utmost concern and crucial for the assurance of consumer satisfaction.

Several carcass, production and postmortem muscle characteristics have been associated with the enhancement and possible prediction of beef palatability. Time-on-feed, subcutaneous fat thickness, early postmortem muscle temperature and pH are traits which have been closely associated with beef palatability, particularly tenderness.

While these selected traits have been examined singularly, few attempts have been made to examine the interrelationships between these traits. Accordingly, this study was conducted to examine the interrelationships between time-on-feed, carcass weight, subcutaneous fat thickness, marbling score and beef palatability, as well as the effects of postmortem temperature and pH on ribeye muscle tenderness.

Materials and Methods

Forty-eight Angus x Hereford steers, approximately 16 months of age with similar frame size (medium) and muscle thickness (No.1) were obtained from a native range stocker operation in northwestern Oklahoma. In order to more specifically address the objectives of this study, care was taken to control age, breed and environmental background. After an initial 24-hour shrink, individual live weights were obtained and the steers were blocked by weight into eight groups to be serially slaughtered at 28-day intervals (0 through 196 days). All steers were dewormed, implanted with Compudose and fed a high concentrate finishing diet (87.5% dry matter, 83.8 Mcal/kg NEm, 54.1 Mcal/kg NEg) except for the 0-day slaughter period which served as a grass-fed control. At the end of each feeding period, a live weight was obtained for each steer and a 4% shrink was deducted to determine shrunk live weight.

All steers were conventionally slaughtered at the Oklahoma State University Meat Laboratory. Within 30 minutes postmortem, one randomly assigned side of each carcass was trimmed of subcutaneous fat over the wholesale rib region (5th to 13th ribs) with an equal number of left and right sides trimmed per slaughter period. During chilling (33°F), ribeye muscle temperature was monitored intermittently for 24 hours with probes inserted into the medial portion immediately anterior to the ninth rib. Approximately 24-hours postmortem, ribeye muscle pH was obtained and three experienced evaluators scored or measured the traits utilized in determining USDA quality and yield grades (USDA, 1980). However, only the control sides were utilized to calculate the quality and yield grades.

The wholesale rib was fabricated and the ribeye roll (IMPS 112) was removed for organoleptic and histological analysis. After a 7 day aging period, two 1.0 inch thick steaks corresponding to the eighth and ninth ribs were fabricated, vacuum packaged, and frozen at -22°F for subsequent taste panel and Instron shear force determinations. Upon completion of the slaughter phase of the study, the steaks were thawed for 24 hours in a 40°F cooler and broiled to 158°F (medium degree of doneness) on Farberware Open-Hearth broilers. An eight-member sensory panel, trained according to American Meat Science Association guidelines for cooking and sensory evaluation of meat (AMSA, 1978), evaluated the ninth rib steak samples for juiciness, tenderness, ease of fragmentation, flavor intensity, and connective tissue amount utilizing eight-point descriptive scales. Instron shear force determination for each eighth rib steak was performed on six .5 inch cores, which were removed after the cooked steaks had cooled to room temperature. A 1.0 inch steak corresponding to the seventh rib was utilized for sarcomere length determination.

Data were analyzed by a split plot analysis of variance. Orthogonal polynomials were used for each treatment (n=48), as well as for the pooled, right and left side data (n=96). Means were separated by Tukey's procedure (Steel and Torrie, 1980). Path coefficients (standard partial regression coefficients) were computed to allow direct comparisons of traits that interrelate (Wright, 1934) to influence tenderness.

Results and Discussion

Performance traits

Slaughter weight and dressing percentage generally increased ($P<.05$) across days-fed (Table 1). Growth rate did not ($P>.05$) differ between the

Table 1. Mean values for performance traits across days-fed.

Days-fed	n	Slaughter weight, lb.	Dressing percentage,%	Cumulative average daily gain,lb.
0	6	762.6[g]	56.8[c]	
28	6	949.3[f]	57.3[c]	5.14[a]
56	6	991.6[ef]	61.1[b]	3.35[b]
84	6	1104.9[de]	61.6[b]	3.51[b]
112	6	1163.4[cd]	64.6[a]	3.22[b]
140	6	1250.0[bc]	64.8[a]	3.09[b]
168	6	1295.0[b]	64.6[a]	2.80[b]
196	6	1429.9[a]	67.0[a]	3.11[b]

[a,b,c,d,e,f,g]Means in the same column that do not have a common superscript letter differ ($P<.05$).

slaughter groups, except for 28 day slaughter group. The steers in the 28-day group may have experienced a compensatory response as a result of being placed on the grain-based diet.

Carcass characteristics

Extending the time cattle receive a high concentrate diet increases subcutaneous fat thickness, yield grade and marbling score. Carcass weight, as well as most weight related traits (fat thickness, longissimus muscle area, and yield grade), increased linearly ($P<.01$) with increased days-fed (Table 2); however, all maturity scores for the individual slaughter periods remained well within "A" maturity. Marbling score and kidney, pelvic, and heart fat percentage showed quadratic trends ($P<.05$), across days-fed and means for these traits did not increase ($P>.05$) after intensive feeding for 112 days. The carcasses from steers fed 112 days were the first to attain the mean marbling score (Small) required for choice quality.

Palatability Attributes

Juiciness and flavor intensity were not significantly influenced by extending the feeding of high concentrates (Table 3). However, feeding the high concentrate diet for 0 through 84-days improved taste panel tenderness scores. Shear force and ease of fragmentation showed little ($P>.05$) improvement after 56 days. Tatum et al. (1980) and Dolezal et al. (1982a) concluded that extending the feeding period beyond 100 days will not substantially improve sensory tenderness. However, it is important to note that both studies utilized a variety of breeds which may partially explain the extended feeding time.

Dolezal et al. (1982b) and Riley et al. (1983) found a close association between subcutaneous fat thickness and palatability. The researchers noted little improvement in palatability once cattle had reached at least .3 inches of subcutaneous fat at the 12th rib. Similar results were obtained in the present study where the steers attained .3 inches between the 56 and 84 day slaughter periods.

Marbling was moderately related to taste panel tenderness ($r=.51$) and shear force ($r=.61$) in Angus x Hereford steers. In addition, marbling was the carcass grade trait most highly correlated with the palatability attributes. In fact, juiciness and flavor intensity were only associated ($P<.05$) with carcass traits related to fatness.

Taste panel tenderness, amount of perceived connective tissue, and shear force values were less desirable ($P<.05$) for the 196 day slaughter period than the 112 day slaughter period. This decrease in sensory values

Table 2. **Mean values for carcass characteristics across days-fed.**

Days-fed	Maturity score[a]	Marbling score[b]	Fat thickness, in.	Ribeye, sq.in.	Carcass weight, lb.	Kidney, heart & pelvic fat, %	Yield grade
0	137.2[d]	254.2[g]	0.12[f]	9.81[f]	433.4[h]	1.0[f]	1.4[g]
28	133.0[d]	299.0[fg]	0.16[f]	10.82[ef]	521.8[gh]	1.3[ef]	1.7[fg]
56	139.0[d]	336.0[efg]	0.27[ef]	12.19[de]	581.4[fg]	1.5[e]	1.7[fg]
84	147.0[cd]	372.8[def]	0.39[e]	11.83[de]	652.1[gef]	1.8[de]	2.4[ef]
112	156.7[c]	472.2[c]	0.57[d]	12.84[cd]	721.3[de]	2.1[cd]	2.9[e]
140	158.0[c]	428.3[cde]	0.59[d]	13.29[cd]	778.2[d]	2.4[c]	3.2[de]
168	156.5[c]	471.7[c]	0.72[cd]	13.10[cd]	804.0[d]	2.3[c]	3.7[cd]
196	161.8[c]	464.2[cd]	0.83[c]	14.45[c]	920.2[c]	2.2[cd]	4.0[c]

[a]Maturity score: A=100-199.
[b]Marbling score: small=400-499; slight=300-399; traces=200-299.
[c,d,e,f,g,h]Means in the same column that do not have a common superscript letter differ ($P<.05$).

Table 3. Mean values for palatability traits.[a]

Item	Juiciness	Ease of fragmentation	Connective tissue	Flavor intensity	Tenderness	Shear force, lb.
Days-fed						
0	4.74	3.66^{f}	5.02^{e}	4.61	3.52^{d}	18.14^{e}
28	4.95	4.46^{ef}	5.51^{de}	4.93	4.20^{d}	14.73^{d}
56	4.96	5.59^{bcd}	6.12^{bcd}	4.83	5.34^{c}	11.16^{bc}
84	5.13	6.11^{bcd}	6.43^{bc}	4.81	5.88^{bc}	9.63^{bc}
112	5.49	6.41^{b}	6.66^{b}	5.04	6.36^{b}	8.40^{b}
140	4.86	5.48^{cd}	6.02^{bcd}	5.03	6.36^{b}	9.39^{bc}
168	5.46	6.39^{bc}	6.34^{bc}	5.03	6.36^{b}	9.39^{bc}
196	4.81	5.27^{de}	5.84^{cd}	4.98	5.33^{c}	11.86^{cd}
Treatment						
Control	5.09	5.65^{b}	6.14^{b}	4.94	5.59^{b}	11.38
Trimmed	5.02	5.19^{c}	5.84^{c}	4.85	5.04^{c}	11.99

[a]Juiciness: 1=extremely dry to 8=extremely juicy; ease of fragmentation; 1=extremely difficult to fragment 8=extremely easy; flavor intensity; 1=extremely bland to 8=extremely intense; amount of connective tissue: 1=abundant to 8=none; tenderness 1=extremely tough to 8=extremely tender.

[bcdef]Means in the same column and within the same item that do not have a common superscript letter differ ($P<.05$).

may be related to carcass maturity. Zinn et al. (1970), utilizing Hereford cattle, indicated that maturity may influence tenderness in cattle fed longer than 180 days. Conversely, others have shown no apparent detrimental effects in extending the feeding period beyond 200 days (Bidner et al., 1981; Dolezal et al., 1982a). However, important cattle age/weight differences at the onset of feeding must be considered when comparing studies.

Postmortem Muscle Characteristics

The 24 hour pH tended to be higher for the steers within the early slaughter groups (Table 4). Carcasses from the 0-day steers had higher ($P<.05$) 24 hour pH values than carcasses from steers fed a high-energy diet for a minimum of 84 days. Bowling et al. (1977) indicated that grass-fed steers had higher ultimate pH values than grain-fed steers and suggested that grass-fed cattle tend to be more susceptible to pre-slaughter stress, which could result in higher pH values.

The rate of temperature decline among time-based slaughter groups for days-fed are illustrated in Figure 1. The mean longissimus muscle temperature at .5 hour postmortem (the initial measurement) did not differ ($P>.05$) among days-fed groups. Steers in the early slaughter periods (0-56 days) chilled at similar rates ($P>.05$). The overall trend reflected that carcasses from steers fed for longer periods of time tended to chill more slowly than carcasses from steers in the earlier slaughter periods. These results imply that carcass fatness and mass altered the chilling rate between slaughter groups.

Simple correlation coefficients indicated a high positive correlation between 2.5 hour postmortem longissimus muscle temperature and carcass

Table 4. Mean values for postmortem muscle characteristics.

Item	Temperature at 2.5 hours, °F	24 hour pH	Sarcomere length, µm
Days-fed			
0	78.4^{f}	5.78^{a}	1.73^{c}
28	82.8^{e}	5.71^{ab}	1.89^{a}
56	86.4^{cd}	5.75^{ab}	1.87^{ab}
84	89.4^{cd}	5.69^{bc}	1.91^{a}
112	93.7^{b}	5.61^{c}	1.80^{bc}
140	92.7^{bc}	5.52^{d}	1.84^{ab}
168	92.8^{bc}	5.53^{d}	1.85^{ab}
196	98.2^{a}	5.53^{d}	1.91^{a}
Treatment			
Control	91.4^{a}	5.61^{b}	1.87^{a}
Trimmed	87.1^{b}	5.67^{a}	1.83^{b}

[a,b,c,d,e,f]Means in the same column that do not have a common superscript letter differ ($P<.05$).

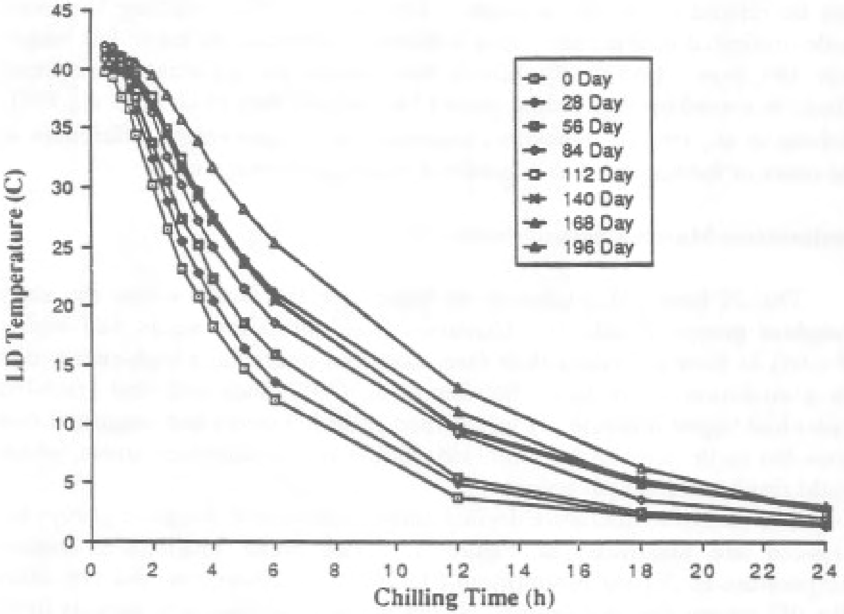

Figure 1. Longissimus muscle temperature for pooled treatment groups versus chilling time across days-fed.

weight, fat thickness and days-fed (.86, .80, .86, respectively). The 2.5 hour temperature was the trait most highly correlated with tenderness and days-fed (.54 and .86, respectively). This is in agreement with Lochner et al. (1980) in which the authors concluded that muscle temperature was most highly correlated with tenderness very early postmortem (2-4 hours). Taste panel tenderness and 2.5 hour longissimus muscle temperature follow similar trends through the 168 day slaughter period.

Few differences existed between slaughter periods for sarcomere length. However, sarcomeres measured for carcasses from the 0-day steers were shorter ($P<.05$) than all other slaughter groups, except for the 112-day group (Table 4). The lack of finish and light carcass weight may have contributed to the shortening of the sarcomeres in the 0-day cattle. Lee and Ashmore (1985) suggested that cold induced toughening is primarily a factor only in rapid chilled, light weight carcasses and has little effect in well finished beef carcasses. Sarcomere length was not significantly related to taste panel tenderness and possessed a low correlation coefficient with shear force.

Treatment Effects

Trimming of subcutaneous fat over the wholesale rib section was conducted to examine the effect of fat thickness, independent of production and carcass characteristics, on postmortem muscle traits and palatability attributes. Marbling score was not significantly different between control (Slight 87) and trimmed (Slight 94) sides. However, the control sides did have larger ($P<.05$) ribeye areas than trimmed sides (12.3 versus 11.9 sq in, respectively). Possibly, natural physical restraints on the ribeye muscle may have been severed due to the removal of the subcutaneous fat on the trimmed sides or the changes may have resulted from dehydration. Trimmed sides chilled at a faster rate ($P<.05$) than control sides (Figure 2), exemplifying the insulatory effect of subcutaneous fat. Also, temperature at 2.5 h for control sides was higher ($P<.05$) than for trimmed sides.

Sensory evaluation revealed that juiciness and flavor intensity were not ($P<.05$) affected by the trimming of subcutaneous fat (Table 3). However, steaks from the trimmed sides were less tender ($P<.05$) and more difficult to fragment ($P<.05$) than the steaks from the control sides. The latter indicates muscle temperature was playing a role in tenderness determination.

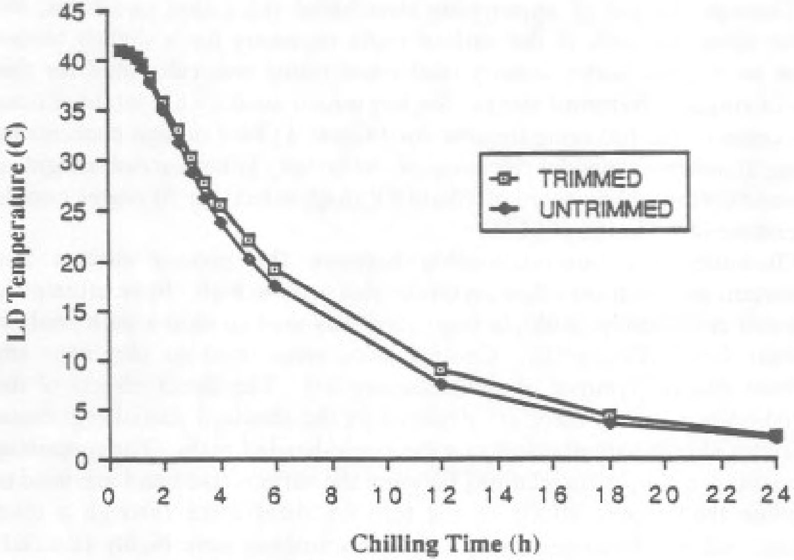

Figure 2. Longissimus muscle temperature for the treatment groups.

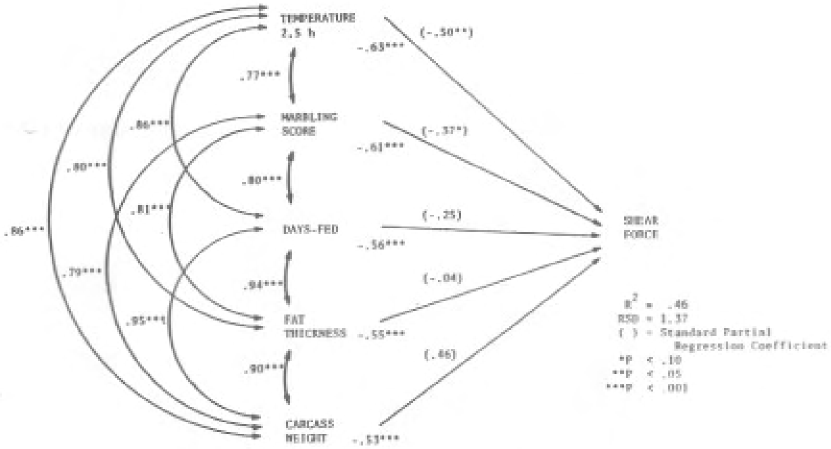

Figure 3. Path coefficient diagram for selected constituents of shear force.

The selected traits in the path analysis accounted for 46% of the variation in shear force. Temperature at 2.5 h had the greatest ($P<.05$) direct effect on shear force. Consequently, indirect paths for other variables had the greatest impact on shear force when routed through 2.5 hour temperature. Magnitudinal order of secondary paths (indirect) involved carcass weight (2nd), marbling score (3rd), and fat thickness (4th).

The results of the study indicated that with increased days on a high concentrate diet, steaks from Angus x Hereford steers markedly improved in tenderness (through 84 days). In addition, early postmortem temperature, fat thickness, carcass weight, and marbling score were associated with improved tenderness values. Among the carcass grade traits, marbling was most highly related to tenderness. The relationship between marbling score and tenderness is undoubtedly represented well in this study through the use of Angus x Hereford steers, a crossbreed known for their ability to marble.

Time-on-feed and the carcass grade traits appear to affect tenderness by delaying carcass chilling rate and enhancing early postmortem muscle temperature. Ribeye muscle temperature at 2.5 hours postmortem had the greatest direct and indirect impact on tenderness.

Literature Cited

AMSA. 1978. Guidelines for Cookery and Sensory Evaluation of Meat. American Meat Science Association. Chicago, IL.

Bidner, T.D. et al. 1982. Acceptability of beef finished on all-forage, forage plus grain or high energy diets. J. Anim. Sci. 53:1181.
Bowling, R.A. et al. 1977. Comparison of forage-finished and grain finished beef carcasses. J. Anim. Sci. 45:209.
Dolezal, H.G. et al. 1982a. Effect of time-on feed on the palatability of rib steaks from steers and heifers. J. Food Sci. 47:368.
Dolezal, H.G. et al. 1982b. Comparison of subcutaneous fat thickness, marbling and quality grade for predicting palatability of beef. J. Food Sci. 47:397.
Lee, Y.B. and C.R. Ashmore. 1985. Effect of early postmortem temperature on beef tenderness. J. Anim. Sci. 60:1588.
Lochner, J.V. et al. 1980. Early postmortem cooling rate and beef tenderness. Meat Sci. 4:227.
Riley, R.R. et al. 1983. Palatability of beef from steer and young bull carcasses as influenced by electrical stimulation, subcutaneous fat thickness and marbling. J. Anim. Sci. 56:592.
Savell, J.W. et al. 1987. National consumer retail beef study: palatability evaluations of beef loin steaks that differed in marbling. J. Food Sci. 52:517.
Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics. McGraw-Hill Book Co., New York.
Tatum, J.D. et al. 1980. Carcass characteristics, time on feed and cooked beef palatability attributes. J. Anim. Sci. 50:833.
USDA. 1980. Official United States standards for carcass beef. AMS-USDA, Washington, DC.
Wright, S. 1934. The method of path coefficients. Ann. Math. Statist. 5:161.
Zinn, D.W. et al. 1970. Beef muscle tenderness as influenced by days on feed, sex, maturity and anatomical location. J. Anim. Sci. 31:307.