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DIET ENERGY DENSITY AND TIME ON FEED EFFECTS ON BEEF *LONGISSIMUS* MUSCLE PALATABILITY[1]

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Summary

To evaluate the combined effects of time on feed and diet energy density on the palatability of beef *longissimus* muscle steaks, we randomly allotted 112 Angus yearling steers to 14 nutritional regimens (eight steers per treatment): control group (C), submaintenance group (S) and 12 groups fed either a low (L), medium (M) or high (H) energy density diet (.771, .992 or 1.28 Mcal NEp/kg, respectively) and slaughtered after 56, 91, 119, 147 (M and H groups only) or 175 (H group only) days on feed. Taste panel evaluations, Instron textural assessments and sarcomere length measurements were conducted on *longissimus* muscle samples collected 7 days postmortem. Taste panel muscle fiber tenderness, overall tenderness, juiciness and flavor intensity scores were not influenced (P>.05) by nutritional regimen. Connective tissue was most detectable in steaks from the S group, but the amount was similar (P>.05) to that detected in the C, L-56 and H-147 groups' steaks. In general, steaks from cattle fed L diets for 91 or more days or M or H diets for 56 or more days had the least amount of detectable connective tissue. Values for peak force and peak force minus initial-yield force were affected (P<.05) by nutritional regimen; however, there was no consistent pattern for these variables. Steaks from cattle in the S group had the shortest *longissimus* muscle sarcomere lengths (1.73 μm). C group sarcomere lengths were shorter than those of all L, M and H diet groups except M-56, but these differences did not affect measurements of muscle fiber tenderness.

(**Key Words:** Nutritional Regimen, Diet Energy Density, Time on Feed, Palatability, Tenderness, Beef.)

Introduction

Palatability is important for consumer acceptance of beef, and diet and length of finishing time may influence beef palatability (Allen *et al.*, 1977). Increasing the time on feed improved taste panel tenderness (Kropf *et al.*, 1975; Shinn *et al.*, 1976, Harrison *et al.*, 1978; Leander *et al.*, 1978) and juiciness scores (Judge *et al.*, 1978). Increases in tenderness may occur early in the feeding period (Zinn *et al.*, 1970) and even as early as after 49 days of feeding (Smith *et al.*, 1977). However, Matthews and Bennett (1962), Moody *et al.* (1970) and Dinius and Cross (1978) found no change in taste panel scores and Warner-Bratzler shear forces as time on feed increased.

Jacobsen and Fenton (1956), Cover *et al.* (1957) and Smith *et al.* (1977) reported that beef palatability improved as diet energy density increased. Yet others have reported no effect of diet energy density on palatability (Callow, 1961; Matthews and Bennett, 1962; Henrickson *et al.*, 1965).

The combined effects of time on feed and diet energy density on beef palatability are still unclear. Crouse *et al.* (1978) stated that longer time on feed was associated with improved taste panel scores within a feeding regimen-diet energy level. However, feeding regimens that involved longer feeding periods for cattle to reach slaughter weight tended to decrease taste panel acceptability.

The purpose of our study was to determine the effect of time on feed and diet energy density on beef *longissimus* muscle palatability.

Materials and Methods

Treatments. One-hundred and twelve Angus yearling steers from a commercial herd were

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randomly assigned (eight per group) to each of 14 nutritional regimens. A control (C) group was slaughtered at the end of a feed adjustment period, and a submaintenance (S) group, expected to lose about .5 kg/day, was fed prairie hay for 28 days, then slaughtered. The 12 remaining groups were fed a diet of low (L), medium (M) or high (H) density (table 1) and slaughtered after 56, 91, 119, 147 (M and H groups only) or 175 (H group only) days on feed. Before the start of the trial, steers were fed corn silage for 4 months and gained .7 kg/day.

Cattle were withheld from feed for 18 to 24 hr before being slaughtered at a commercial packing house. Carcass data were collected after carcasses were chilled for 24 hours. Wholesale ribs from the right side of each carcass were delivered to the Kansas State University Meat Laboratory for sampling.

Sample Location. The *longissimus* muscle was removed from each rib 7 days postmortem and immediately fabricated into 2.5-cm thick steaks. A steak was removed from the 12th rib area for histological analysis, and two steaks were removed from the 10th rib area for taste panel and Instron textural analyses. All steaks were individually wrapped in freezer paper, frozen and stored at −26 C until analyzed.

Taste Panel Analysis. Steaks for taste panel analysis were thawed at 2 C overnight and oven-broiled in a rotary oven at 177 C to an internal temperature of 66 C as determined by a glass thermometer placed in the geometric center of each steak.

Cores 1.3 cm in diameter were removed from each steak for taste panel evaluations. A six-member panel evaluated each steak for detectable connective tissue, muscle fiber tenderness, overall tenderness, juiciness and flavor intensity using eight-point scales for each factor (1 = abundant connective tissue, extremely tough, extremely dry or extremely bland flavor; 8 = no detectable connective tissue, extremely tender, extremely juicy or extremely intense flavor). Cores from six steaks representing different nutritional regimens were served at each session. Panelists were screened, trained and tested according to AMSA (1978) recommendations.

TABLE 1. DIET COMPONENTS ON AS-FED BASIS

Ingredient	Internat'l Ref. No.	Diet[a] Low energy	Medium energy	High energy
		(%)		
Corn	4-02-913	17.9	27.1	38.6
Wheat	4-05-268	17.9	27.1	38.6
Sorghum silage	3-04-468	16.8	16.5	16.3
Prairie hay	1-07-956	42.9	24.2	0
Supplement[b]		4.6	5.0	1.28

[a]Diet energy densities, (megacalories NEp/kilogram): low = .771, medium = .992, high = 1.28.

[b]Included soybean meal, ground limestone, dicalcium phosphate, salt, trace minerals and vitamins.

Instron Textural Analysis. Steaks for Instron measurements were cooked the same way as the taste panel steaks. An Instron Model 1123 equipped with a 500-kg load cell and strip chart recorder was used to record Warner-Bratzler force-deformation curves. Three 1.3-cm diameter cores were removed near the subcutaneous edge of each steak with a drill press unit. Each core was cut twice with an Instron Warner-Bratzler attachment. Peak force, initial-yield force and peak force minus initial-yield force (Bouton *et al.*, 1975) were determined from the force-deformation curves (Bouton and Harris, 1972).

Sarcomere Length. Five cores 1.3 cm in diameter were removed from the medial, central, lateral, dorsal and ventral positions of each steak and used for histological determinations. Cores were placed in a plastic bag, sealed, frozen and stored at −26 C until analyzed. After the cores had thawed for 1 hr at room temperature, the center third from each was removed and blended at low speed in a Waring Blendor with 40 ml of cold, .25 M sucrose solution for 30 to 60 seconds. Sarcomere lengths were measured with a Wild phase contrast microscope at ×750. The total length of 10 sarcomeres from each of 25 myofibrils was measured with an eyepiece filar micrometer for estimation of average sarcomere length.

Statistical Analysis. Data were analyzed by analysis of variance and resultant F tests for nutritional regimen effects. Duncan's mean separation techniques were used to separate treatment means.

Results and Discussion

Production and Carcass Characteristics. Nutritional regimens used in this study were effective in causing differences in production and carcass characteristics. Average beginning weight of all steers was 280 kilograms. Ending-test weights for groups fed 56, 91, 119, 147 and 175 days averaged 352, 375, 409, 469 and 485 kg, respectively. Average daily gain for the S, L, M and H diet groups was −.21, .81, 1.18 and 1.35 kg/day, respectively.

In general, group means for USDA yield (table 2) and quality (table 3) grade factors increased as diet energy density (DED) increased and as time on feed (TOF) increased. Means for hot carcass weight; ribeye area; kidney, pelvic and heart fat, adjusted fat thickness were lowest for carcasses from the S group and highest for the H-175 group. Yield grade number was lowest (1.1) for the L-56 group and highest (3.4) for the H-175 group. All carcasses were within the A-maturity classification. Marbling scores and quality grades ranged from practically devoid and Standard (S group) to small and Choice (H-175 group). Similar results for carcass traits with increasing DED (Guenther *et al.*, 1965; Prior *et al.*, 1977; Smith *et al.*, 1977; Ferrell *et al.*, 1978) and increasing TOF (Moody *et al.*, 1970; Shinn *et al.*, 1976; Dinius and Cross, 1978; Leander *et al.*, 1978) have been reported.

Palatability Traits. Muscle fiber tenderness,

TABLE 2. USDA YIELD GRADE FACTORS FOR DIET ENERGY DENSITY AND TIME ON-FEED NUTRITIONAL REGIMENS

Diet[a]	Time on feed, days						
	0	28	56	91	119	147	175
				Hot carcass weight, kg			
C	156.6^{j}						
S		155.9^{j}					
L			175.8^{i}	189.5^{ghi}	206.8^{efg}		
M			188.1^{hi}	213.0^{ef}	241.4^{d}	269.6^{c}	
H			196.2^{fgh}	223.3^{e}	252.3^{d}	292.7^{b}	296.7^{b}
				Ribeye area, cm²			
C	59.4^{d}						
S		51.1^{e}					
L			62.7^{d}	58.9^{d}	61.5^{d}		
M			61.5^{d}	64.4^{cd}	69.1^{bc}	69.6^{bc}	
H			62.9^{d}	64.8^{cd}	72.3^{b}	72.8^{b}	74.2^{b}
				Kidney, pelvic and heart fat, %			
C	1.5^{f}						
S		1.0^{gf}					
L			$.6^{i}$	1.5^{f}	1.2^{fg}		
M			$.7^{hi}$	2.0^{e}	2.0^{e}	2.9^{c}	
H			$.8^{hi}$	2.5^{d}	2.0^{e}	2.9^{c}	3.6^{b}
				Adjusted fat thickness, cm			
C	$.28^{fgh}$						
S		$.10$ $.10^{h}$					
L			$.13^{gh}$	$.33^{fg}$	$.32^{fgh}$		
M			$.21^{gh}$	$.44^{ef}$	$.56^{e}$	$.84^{d}$	
H			$.27^{fgh}$	$.78^{d}$	$.78^{d}$	1.14^{c}	1.44^{b}
				Yield grade			
C	1.4^{ij}						
S		1.6^{hi}					
L			1.1^{j}	1.8^{fghi}	1.7^{ghi}		
M			1.4^{ij}	1.9^{fgh}	2.0^{efg}	2.7^{cd}	
H			1.4^{ij}	2.4^{de}	2.2^{ef}	3.1^{bc}	3.4^{b}

[a]C = control; S = submaintenance; L = low, M = medium, H = high energy diet density.

[b,c,d,e,f,g,h,i,j]Nutritional regimen means within a factor without a common superscript letter are different (P<.05).

TABLE 3. USDA QUALITY GRADE FACTORS FOR DIET ENERGY DENSITY AND TIME ON FEED NUTRITIONAL REGIMENS

	Time on feed, days						
Diet[a]	0	28	56	91	119	147	175
				Avg maturity[b]			
C	A-36^{j}						
S		A-50^{efgh}					
L			A-44^{ghij}	A-47^{fghi}	A-44^{ghij}		
M			A-40^{hij}	A-44^{ghij}	A-37^{j}	A-56^{ef}	
H			A-37^{j}	A-41^{hij}	A-44^{ghij}	A-57^{e}	A-52^{efg}
				Marbling score[bc]			
C	Tr-12^{j}						
S		PD-80^{j}					
L			PD-82^{j}	Tr-15^{j}	Tr-42^{ij}		
M			Tr-29^{ij}	Sl-01^{ghi}	Sl-26^{fgh}	Sm-05^{ef}	
H			Tr-58^{hij}	Sl-42^{fg}	Sl-95^{ef}	Sm-02^{ef}	Sm-59^{e}
				USDA quality grade[bd]			
C	St-56^{j}						
S		St-40^{j}					
L			St-46^{j}	St-58^{j}	St-77^{ij}		
M			St-66^{ij}	G-14^{hi}	G-31^{gh}	G-87^{ef}	
H			St-80^{ij}	G-48^{fgh}	G-77^{efg}	G-87^{ef}	C-08^{e}

[a]C = control; S = submaintenance; L = low, M = medium, H = high diet energy density.

[b]0 to 33 = low, 34 to 66 = average, 67 to 100 = high.

[c]PD = practically devoid, Tr = traces, S1 = slight and Sm = small amounts of marbling.

[d]St = standard, G = good, C = choice; inconsistencies between quality grade and marbling score are due to averaging.

[e,f,g,h,i,j]Nutritional regimen means within a factor without a common superscript letter are different (P<.05).

overall tenderness, juiciness and flavor intensity scores (table 4) were not influenced (P>.05) by nutritional regimen. Others have reported no effects of TOF on palatability (Matthews and Bennett, 1962; Moody *et al.*, 1970; Dinius and Cross, 1978) or of DED on palatability (Callow, 1961; Matthews and Bennett, 1962; Henrickson *et al.*, 1965).

Detectable connective tissue scores were affected (P<.05) by nutritional regimen. Steaks from the S group had the most detectable connective tissue, but the amount was similar to that of steaks from the C, L-56 and H-147 groups. Detectable amounts of connective tissue in steaks from cattle fed L diets for 91 or more days or M or H diets for 56 or more days were similar to amounts in steaks representing nutritional regimens with the least detectable connective tissue (M-91 and H-56). Batterman *et al.* (1952) reported a dilution in total collagen of meat from cows fed for 67 and 74 days. Smith *et al.* (1977) reported lower taste panel tenderness and acceptability scores for steaks from steers off grass than for those from steers fed a 20 or 60% roughage diet. However, the differences were small and disappeared after 49 days of feeding of a 20 or 60% forage diet. Kropf *et al.* (1975), Shinn *et al.* (1976), Harrison *et al.* (1978) and Leander *et al.* (1978) also reported increasing tenderness with increased TOF.

Objective Textural Traits. Means (table 5) for Warner-Bratzler peak force and peak force minus initial-yield force (a connective tissue tenderness indicator) were affected (P<.05) by nutritional regimen; however, differences were small and no consistent pattern for these variables was evident for DED and TOF nutritional regimens. No effects of nutritional regimen on Warner-Bratzler initial-yield force measurements (a muscle fiber tenderness indicator) were detected. Matthews and Bennett

TABLE 4. *LONGISSIMUS* MUSCLE TASTE PANEL MEANS FOR DIET ENERGY DENSITY AND TIME ON FEED NUTRITIONAL REGIMENS

Diet[a]	Time on feed, days						
	0	28	56	91	119	147	175
	Muscle fiber tenderness[b]						
C	6.8						
S		6.8					
L			6.8	6.8	6.8		
M			6.8	6.8	6.8	6.7	
H			7.0	6.7	6.8	6.8	7.2
	Detectable connective tissue[b]						
C	6.8[de]						
S		6.5[e]					
L			6.7[de]	7.1[cd]	7.0[cd]		
M			7.0[cd]	7.3[c]	7.1[cd]	7.1[cd]	
H			7.3[c]	7.0[cd]	7.0[cd]	6.8[cde]	7.1[cd]
	Overall tenderness[b]						
C	6.7						
S		6.6					
L			6.6	6.8	6.8		
M			6.8	6.9	6.7	6.8	
H			7.0	6.7	6.8	6.6	7.1
	Juiciness[b]						
C	6.4						
S		6.4					
L			6.0	5.9	6.0		
M			5.8	5.9	6.3	5.8	
H			6.0	6.0	5.8	6.3	6.4
	Flavor intensity[b]						
C	6.5						
S		6.8					
L			6.2	6.3	6.7		
M			6.3	6.2	6.5	6.4	
H			6.6	6.3	6.4	6.4	6.6

[a]C = control; S = submaintenance; L = low, M = medium, H = high diet energy density.

[b]Scores based on an eight-point scale for each factor (1= abundant connective tissue, extremely tough, extremely dry or extremely bland flavor; 8 = no connective tissue, extremely tender, extremely juicy or extremely intense flavor).

[c,d,e]Nutritional regimen means within a trait without a common superscript letter are different ($P<.05$).

(1962), Moody *et al.* (1970) and Dinius and Cross (1978) reported no differences in Warner-Bratzler shear values for cattle on feed for increasing lengths of time. Zinn *et al.* (1970) reported that shear values decreased early in the feeding period but increased later in the feeding period.

Sarcomere Length. Sarcomere length (table 5) was influenced ($P<.05$) by nutritional regimen, but sarcomere length differences did not affect taste panel assessments of muscle fiber tenderness. Steaks from cattle fed the S diet had the shortest *longissimus* muscle sarcomere lengths. C group sarcomere lengths were shorter than those of all L, M and H diet groups except M-56. With 56 or more days on feed, all sarcomeres were longer than 1.85 micrometers. Bouton *et al.* (1973) stated that sarcomere lengths greater than 1.8 μm did not correlate well with tenderness differences in lambs.

TABLE 5. *LONGISSIMUS* MUSCLE WARNER-BRATZLER AND SARCOMERE LENGTH MEANS FOR DIET ENERGY DENSITY AND TIME ON FEED NUTRITIONAL REGIMENS

	Time on feed, days						
Diet[a]	0	28	56	91	119	147	175
	Warner-Bratzler peak force, kg						
C	1.98[cde]						
S		2.16[bcde]					
L			2.02[cde]	2.01[cde]	2.15[bcde]		
M			1.96[cde]	2.55[b]	1.95[cde]	2.14[bcde]	
H			1.76[de]	2.32[bc]	2.26[bcd]	2.35[bc]	1.72[e]
	Warner-Bratzler initial-yield force, kg						
C	1.53						
S		1.55					
L			1.71	1.70	1.78		
M			1.69	1.97	1.50	1.80	
H			1.51	1.90	1.94	2.02	1.41
	Warner-Bratzler peak force minus initial-yield force, kg						
C	.45[bc]						
S		.60[b]					
L			.31[c]	.31[c]	.37[c]		
M			.27[c]	.58[b]	.45[bc]	.35[c]	
H			.26[c]	.42[bc]	.32[c]	.34[c]	.31[c]
	Sarcomere length, μm						
C	1.84[g]						
S		1.78[h]					
L			1.96[de]	1.92[ef]	2.00[bcde]		
M			1.87[fg]	1.96[de]	2.03[bcd]	2.01[bcd]	
H			1.97[cde]	2.04[bcd]	2.06[b]	2.05[bc]	2.02[bcd]

[a]C = control; S = submaintenance; L = low, M = medium, H = high diet energy density.

[b,c,d,e,f,g,h]Nutritional regimen means within a factor without a common superscript letter are different ($P<.05$).

Carcasses of steers in the L, M and H groups were heavier and generally fatter than those of steers in the C or S groups and may have chilled slower, resulting in less sarcomere shortening. Meyer *et al.* (1977) reported faster chilling rates for defatted loins of beef carcasses than for loins with fat cover. Smith *et al.* (1976) stated that heavier lamb carcasses with greater fat thickness had longer *longissimus* sarcomeres than lighter carcasses with less fat cover.

A major reason for conducting this study was to examine the combined effects of DED and TOF on palatability. Even though USDA quality grades ranged from Standard to Choice, palatability differences within this population of steaks were small and were more related to detectable connective tissue than to muscle fiber tenderness. Palatability differences, when present, disappeared with as little as 56 days of feeding. Our data indicate that DED and TOF have minimal effects on palatability of A-maturity *longissimus* muscle. If DED and TOF played a role in beef palatability, the effect may have occurred before the start of the trial during the early growing or preconditioning periods.

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