

Influence of Sire Growth Potential, Time on Feed, and Growing-Finishing Strategy on Cholesterol and Fatty Acids of the Ground Carcass and Longissimus Muscle of Beef Steers^{1,2}

D. C. Rule^{*,3}, M. D. MacNeil[†], and R. E. Short[†]

^{*}Department of Animal Science, University of Wyoming, Laramie 82071 and

[†]USDA ARS, Fort Keogh Livestock and Range Research Laboratory, Miles City, MT 59301

ABSTRACT: The purpose of this study was to determine how diverse beef cattle production systems affect fatty acids and cholesterol of meat. Crossbred cows were bred by AI to high (H) or moderate (M) growth rate potential bulls to produce spring- or fall-born calves. Steer calves from these matings were placed on finishing diets at three ages. Spring-born steers were started at 6 or 18 mo of age (A6 and A18), and fall-born calves were started at 12 mo of age (A12). Slaughter times were 0, 90, 180, and 270 d for A6; 68, 136, and 204 d for A12; and 0, 45, 90, and 135 d for A18. Four steers of each type were slaughtered in each of 2 yr for each sire type × time on feed × slaughter group. Fatty acids and cholesterol of ground carcass and longissimus muscle (LM) were determined by GLC. Carcass fat increased faster in M than in H steers ($P < .01$). Ground carcass cholesterol was greater for M steers ($P = .06$) than for H steers

because of the greater fat content in the M ground carcass. No differences in LM cholesterol were observed for sire growth potential or time on feed. Fatty acid differences in ground carcass with time on feed were due primarily to decreases in 18:0 and increases in 18:1. The LM saturated and monounsaturated fatty acids changed little with time on feed, but total saturates were greater for M steers (44.5%) than for H steers (42.8%) ($P = .02$). A18 steers of H sires had the greatest ($P = .04$) ratio of 18:0 plus unsaturates to 14:0 plus 16:0 (most hypocholesterolemic). We conclude that cholesterol in lean muscle is not altered by the sire growth potential × time on feed × growing-finishing strategy imposed, and that lean beef from steers sired by H bulls and backgrounded before finishing may produce meat with the healthiest lipid composition.

Key Words: Beef Cattle, Cholesterol, Fatty Acids, Sires, Nutrition, Maturity

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Introduction

Beef provides consumers with high-quality protein and associated vitamins and minerals; however, its saturated fatty acid and cholesterol content has led to a negative image of beef by some consumers. Increasing proportions of 18:0 and 18:1 in beef would be of

most benefit to red meat consumers (Mattson and Grundy, 1985; Bonanome and Grundy, 1988). Sex and breed effects on proportions of major fatty acids in adipose tissue have been reported for several cattle breeds (Eichhorn et al., 1985, 1986; May et al., 1993; Zembayashi et al., 1995). Nutritional factors also affect tissue fatty acids in cattle; for example, forage compared with grain feeding results in greater unsaturated fatty acids (Miller et al., 1981; Marmer et al., 1984). Cholesterol content of bovine muscle and adipose tissue has proven resistant to nutritional (Miller et al., 1981; Eichhorn et al., 1986) and breed effects (Eichhorn et al., 1986; Wheeler et al., 1987). However, it is not known whether sire breed, maturity, and nutritional background interact to affect cholesterol in beef. The purpose of the present study was to determine whether sire growth potential, time on feed and growing-finishing strategy influence cholesterol concentration and fatty acid composition of ground carcass and longissimus muscle (LM) of beef steers.

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³To whom correspondence should be addressed.

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Materials and Methods

Steer calves were produced by breeding crossbred cows (various crosses of Angus, Charolais, Hereford, Red Angus, and Tarentaise) to either high yearling weight index Charolais bulls (high growth potential sires, **H**) or to average yearling weight index Line One Hereford bulls (moderate growth potential sires, **M**). Calves from these matings were born in April (spring-born) or October (fall-born), castrated shortly after birth, and weaned in late September (spring-born) or April (fall-born). After weaning at 6 mo of age (**A6**), a random sample of the spring-born steers was put directly on a finishing diet that contained (DM basis) 40% corn silage, 56.2% barley, and 3.8% soybean meal/mineral supplement. Another random sample of spring-born steers was put on a growing diet during the winter (56.7% corn silage, 39.3% grass hay, and 4.0% soybean meal/mineral supplement), grazed on range forage during the summer (May through September), and put on a finishing diet in late September at 18 mo of age (**A18**; 19.3% corn silage, 77.9% barley, and 2.8% soybean meal/mineral supplement). The fall-born steers were grazed on range forage during the summer with the spring-born yearling steers and then put on a finishing diet in September at 12 mo of age (**A12**; 19.3% corn silage, 77.9% barley, and 2.8% soybean meal/mineral supplement).

Steers were slaughtered at the beginning and at three equally spaced times during the finishing period for spring-born steers (**A6** at 0, 90, 180, and 270 d; **A18** at 0, 45, 90, and 135 d on feed), and at three equally spaced times for fall-born steers (**A12** at 68, 136, and 204 d on feed). There were four H- and four M-sired steers slaughtered at each time period within each year, and the experiment was repeated over 2 yr. Fall-born steers were included in only the last year.

The right half of each carcass was boned, ground through a 1.6-cm-mesh blade, mixed, and reground through a .5-cm-mesh blade. Subsamples (100 g) were stored at -20°C for later analyses of total fat, cholesterol, and fatty acid composition. A 20-g slice of 12th rib LM was removed from each carcass. Samples were placed in plastic bags, the air space was eliminated, and the bags were sealed and stored at -20°C . Within 60 d, samples were thawed, and visible depot fat of the LM sample was dissected. Samples of ground carcass and LM were then freeze-dried for 48 h and homogenized for 15 s by using a home-style electric grinder. Extraction of total lipids was accomplished using 3.8 mL of chloroform-methanol-water (1:2:.8; Bligh and Dyer, 1959) to extract 150 mg of dried tissue by vortex-mixing for 4 h in 16-mm \times 125-mm screw-cap tubes (Rule et al., 1994). Total lipids were saponified (Busboom et al., 1991), and fatty acid methyl esters were prepared by using BF_3 in methanol (Morrison and Smith, 1964). Fatty acids

were analyzed with GLC (Rule et al., 1994), and heneicosanoic acid (21:0) was used as the internal standard. Cholesterol content was determined by GLC using an SPB-1, fused capillary column (30 mm \times .53 mm i.d.; Suppelco, Bellefonte, PA) with column temperature at 250°C and detector and injector temperatures at 300°C . Helium was used as carrier gas with a 1:10 split ratio. Stigmasterol was used as the internal standard; the detector response factor for stigmasterol was previously reported as 1.0 relative to cholesterol with this column (Bonsell et al., 1993). Lipid percentage in the ground carcass was determined according to AOAC (1990) procedures.

Data were subjected to analysis of variance using SAS (1990) procedures for general linear models. The model used was for a split-plot design and type III sums of squares were computed. Sire growth potential, growing-finishing strategy, slaughter date within growing-finishing strategy, and the interactions among these sources of variation were in the whole-plot. Cut (ground carcass and LM) and interactions of cut with whole-plot effects were accounted for in the subplot. Effects in the whole-plot were tested using the residual variation between animals. Effects in the subplot were tested with residual variation within animals. Means were separated using *t*-tests in the presence of significant *F*-statistics in the analysis of variance. Fatty acids with significant peaks were reported in the tables. Only the major fatty acids (16:0, 18:0, 18:1, and 18:2) are presented and discussed.

Results and Discussion

Carcass Lipid

For H and M steers, carcass weight and fat percentage increased ($P < .01$) with time on feed (Table 1). The H steers had less overall carcass lipid (21.6%) than M steers (24.8%) ($P < .01$). Regardless of growing-finishing strategy, carcass lipid percentage in steers finished for the longest time was greater in steers of M sires (31.4%) than in steers of H sires (27.0%; ($P = .02$ for **A6**; $P = .006$ for **A12**; $P = .05$ for **A18**).

The change in carcass lipid percentage was affected by growing-finishing strategy and sire type. Carcass lipid of H, **A6** steers increased by 17.9 percentage units, and M, **A6** steers had an 18.4 percentage unit increase during finishing. The main difference between H and M steers was in their ending carcass lipid percentages. For **A12** steers, H increased carcass fat percentage by 7.9 percentage units and M increased it by 12.2 percentage units. Although M and H steers had similar carcass fat percentages when they entered the feedlot ($P = .4$) M deposited fat at a greater rate to significantly exceed H values in **A12** steers ($P = .006$).

Table 1. Carcass weight, carcass fat percentage, and cholesterol concentration of the ground carcass and longissimus muscle (LM)

Age group ^a and days to slaughter ^b	Carcass weight, kg ^c	Carcass fat ^a	Cholesterol concentration, mg/100 g	
			Ground carcass	LM
High sire growth potential				
A6				
0	123.5	11.1	59.2	56.2
90	168.6	20.0	62.0	54.3
180	240.5	23.8	55.7	50.6
270	324.2	29.0	58.8	52.4
A12				
68	201.2	16.9	47.4 ^e	56.1
136	302.3	22.8	61.3 ^d	52.8
204	327.4	24.8	63.4 ^d	55.5
A18				
0	223.1	15.4	50.4	54.1
45	277.6	19.2	57.4	49.3
90	336.1	27.0	59.7	52.8
135	397.9	27.1	59.6	51.1
Medium sire growth potential				
A6				
0	110.1	14.4	57.7	58.4
90	147.8	21.9	58.5	55.0
180	217.9	27.8	60.3	53.5
270	268.1	32.8	63.2	55.6
A12				
68	183.9	19.0	62.6 ^e	47.9
136	259.6	29.0	67.2 ^{de}	53.2
204	306.1	31.2	67.3 ^d	59.6
A18				
0	198.0	15.0	53.1 ^e	54.6
45	277.4	22.9	57.9 ^{de}	51.8
90	317.8	28.1	64.7 ^d	53.9
135	368.0	30.3	65.8 ^d	52.2
SD	30.4	3.2	8.0	7.2

^aAge when steers entered the feedlot: A6, 6 mo; A12, 12 mo; A18, 18 mo.

^bNumber of days from entering the feedlot.

^cCarcass weight and carcass fat increased with time on feed within each sire growth potential and age group ($P < .01$) except for carcass fat of A12, 136 d and A12, 204 d, High ($P = .37$); A18, 90 d and A18, 135 d, High ($P = .90$); A12, 136 d and A12, 204 d, Medium ($P = .35$); and Y21 and Y22.5, Medium ($P = .17$).

^{d,e}Within a sire growth potential and age group, means with different superscripts are different ($P < .05$).

Cholesterol Concentration of the Ground Carcass and Longissimus Muscle

Ground carcass cholesterol was greater in M steers than in H steers (61.7 vs 57.7 mg/100 g, $P = .02$; Table 1). Steers of each growing-finishing strategy sired by H bulls tended to have less cholesterol concentration at the heaviest weights than steers from M sires ($P = .06$ for A6; $P > .1$ for A12 and A18 comparisons between H and M). The difference in cholesterol concentration between H and M carcasses was likely due to differences in carcass fat, which was greater in M- than in H-sired steers. For H and M steers, cholesterol in the ground carcass was affected similarly by time on feed, as seen by the growing-finishing strategy within each sire growth potential. For ground carcass of A6 steers, no effect of time on feed was observed ($P = .59$ for H; $P = .30$ for M). Cholesterol concentration in the ground carcass of A12 increased

abruptly for steers of both sire types ($P = .02$ for H; $P = .06$ for M) but was unchanged in the heaviest animals. For A18 steers, cholesterol concentration increased with time on feed ($P = .07$ for H; $P = .02$ for M).

Cholesterol concentration of LM, dissected free of depot fat, was not affected by sire growth potential ($P = .4$) or time on feed within any growing-finishing strategy ($P = .3$). In contrast to observations on ground carcass, in which cholesterol concentration tended to increase at the heaviest weight, no change occurred for LM. Moreover, cholesterol concentration of the ground carcass of M steers was greater ($P = .02$) than that of H, but no sire type effect was observed for LM. The ground carcass was a composite of all carcass muscles and adipose tissues. However, the LM samples were dissected free of depot fat. The lack of sire type effect on cholesterol concentration of

the defatted LM might suggest that the sire type effect on ground carcass cholesterol was due to differences in carcass fat (24.8% for M and 21.6% for H, $P < .01$). Wheeler et al. (1987) reported cholesterol concentrations for LM that were similar to those of the present study. Wheeler et al. (1987) also reported cholesterol concentrations for adipose tissue (92 to 99 mg/100 g) that were considerably higher than those for LM. If the concentration of cholesterol in bovine adipose tissue was presumed to be 100 mg/100 g (Wheeler et al., 1987), then for every 1 mg/100 g increase in cholesterol, the fat content would be 1% greater. However, by adjusting the ground carcass cholesterol data for ground carcass fat percentages no effect ($P = .44$) of the covariate (fat) was observed (data not shown). Apparently, variation in ground carcass cholesterol concentration was not consistent with the increased ground carcass fat percentage with time on feed. Thus, time on feed and sire growth potential may have contributed to differences in ground carcass cholesterol concentration.

The present study also highlights the low cholesterol concentration of a common serving of beef. The cholesterol concentration of LM was from 45 to 55 mg/100 g. The cholesterol contribution of intramuscular adipose tissue in the LM of USDA Choice carcasses was reported to be 2.7 mg/100 g (Sweeten et al., 1990). Thus, an 85-g serving of raw, lean beef contains approximately 42 mg of cholesterol which represents 14% of the recommended daily cholesterol intake (300 mg; Green and Feldman 1991).

The lack of an effect of sire type on cholesterol concentration indicates that genetic diversity between steers from H and M bulls was not at a locus for which muscle cholesterol was influenced. Wheeler et al. (1987) did not observe differences in LM cholesterol content between Chianina and Hereford \times Angus steers and heifers, nor did Eichhorn et al. (1986) in muscles of several cattle breeds. Nutritional background of cattle also was not a factor dictating cholesterol concentration in muscle (Miller et al., 1981) unless the fat content of the muscle was increased (Miller et al., 1986) or when grain feeding was prolonged (Miller et al., 1987). Thus, breed, nutrition, and sex do not affect the cholesterol concentration of bovine skeletal muscle. The present study further confirms that sire growth potential, time on feed, and growing-finishing strategy do not interact to alter cholesterol in muscle of cattle.

Genetic changes that would lead to differences in muscle cholesterol concentration would probably be associated with marked changes in structure of the muscle cell. Cholesterol is associated with cell membranes (Hauser and Poupart, 1991). The distribution of cholesterol in membranes is such that its association with phosphatidyl choline is thermodynamically more favorable than association with other phospholipids, for example phosphatidyl ethanolamine (Yeagle, 1991). In bovine LM, phosphatidyl choline is

the major phospholipid, and it is nearly twice as abundant as phosphatidyl ethanolamine (Christie, 1981). Membrane cholesterol has a number of functions. Cholesterol may have a fluidizing effect in membranes that contain a high proportion of saturated fatty acids (Cullis and Hope, 1985). For example, erythrocyte membranes and myelin contain high concentrations of cholesterol and little unsaturated fatty acid, whereas membranes of more metabolically active membranes, such as sarcoplasmic reticulum, are more unsaturated and contain less cholesterol (Cullis and Hope, 1985). Thus, altering the cholesterol concentration of muscle may require a marked redistribution of phospholipids in cells as well as marked changes in unsaturation of the membrane fatty acids. To accomplish this, the genetic difference from conventional beef cattle breeds would have to be quite large. In the present study, changes in fatty acid composition were observed for the various sire type \times time on feed \times nutritional background treatments. However, changes in fatty acids apparently were not great enough to cause alterations in LM cholesterol concentration.

Fatty Acid Composition of Total Lipids

Weight Percentage in the Ground Carcass. Fatty acid composition of ground carcass of H and M steers is presented in Table 2. Regardless of sire growth potential, weight percentages of 16:0, 18:0, and 18:2 tended either to decrease with time on feed or to remain essentially unchanged, as with 16:0. Weight percentages of 18:1 increased with time on feed. For example, 18:1 of A6 steers of H bulls increased from 34.7 to 45.6% ($P < .01$). For A6 and A18 steers, the weight percentage of total saturated fatty acids decreased with time on feed ($P < .05$). The opposite effect was observed for total monounsaturated fatty acids. Total polyunsaturated fatty acids decreased ($P < .01$) with time on feed for essentially all steers.

Interactions between sire type and growing-finishing strategy were observed for 16:0 ($P = .04$), 18:0 ($P < .01$), and total polyunsaturated fatty acids ($P = .05$) in the ground carcass. In A6, H steers 16:0 decreased with time on feed by 11% ($P = .02$), whereas no difference in 16:0 was observed for A6 steers from M sires. A steady decline in 18:0 in ground carcass was observed for A12 and A18 steers of both sire types. In A6 steers from H sires a decrease ($P = .02$) in 18:0 was not observed until the third slaughter, but 18:0 in M, A6 steers was 13% greater ($P < .01$) by the second slaughter and then decreased ($P < .01$) by 17% by the third slaughter period. The interaction observed for total polyunsaturated fatty acids occurred because A12 steers from H sires had decreased levels ($P < .01$) at the second slaughter but they increased to initial levels ($P < .01$) by the third slaughter period.

Weight Percentage in the Longissimus Muscle. Fatty acid composition of LD lipids is presented in Table 3.

Table 2. Fatty acid weight percentage of ground carcass lipids

Age group ^a and days to slaughter ^b	14:0	14:1	16:0	16:1	17:0	17:1	18:0	18:1	18:2	18:3	20:4	SAT ^c	PUFA ^d	MUFA ^e
High sire growth potential														
A6														
0	6.6 ^f	2.2 ^f	30.0 ^f	5.9	1.3 ^f	.9	15.3 ^f	34.7 ⁱ	1.8 ^f	.6 ^f	.7 ^f	53.1 ^f	3.2 ^f	40.7 ⁱ
90	4.0 ^g	1.4 ^g	28.7 ^{fg}	5.6	1.1 ^g	.9	16.1 ^f	40.4 ^h	1.3 ^g	.2 ^g	.3 ^g	49.9 ^g	1.7 ^g	46.1 ^h
180	3.8 ^g	1.5 ^g	27.7 ^{gh}	6.1	1.0 ^{gh}	1.0	14.3 ^{fg}	43.2 ^g	1.2 ^g	.1 ^g	.3 ^g	46.8 ^h	1.6 ^g	49.2 ^g
270	3.3 ^h	1.4 ^g	26.7 ^h	6.2	.9 ^h	1.0	13.1 ^g	45.6 ^f	1.5 ^{fg}	.1 ^g	.3 ^g	44.0 ⁱ	1.9 ^g	51.7 ^f
A12														
68	3.0	1.2	25.2	5.2	1.4	1.1	16.1 ^f	44.8	1.5 ^f	.2 ^f	.3	45.7	2.0 ^f	50.0
136	3.2	1.3	25.7	6.0	1.1	1.0	14.0 ^{fg}	46.1	1.3 ^g	.1 ^g	.3	44.0	1.7 ^g	52.1
204	3.0	1.2	25.2	5.7	1.2	1.2	12.9 ^g	47.5	1.7 ^f	.1 ^g	.3	42.3	2.1 ^f	53.2
A18														
0	3.1	1.6 ^h	26.1	6.3	1.4	1.3	16.2 ^h	41.3 ⁱ	1.9 ^f	.5 ^f	.4 ^f	46.7 ^f	2.8 ^f	47.6 ^h
45	3.0	1.3 ^g	26.1	5.8	1.2	1.1	15.5 ^{fg}	44.0 ^{gh}	1.4 ^g	.3 ^g	.3 ^g	45.9 ^{fg}	2.1 ^g	49.8 ^{gh}
90	2.8	1.2 ^g	25.5	5.9	1.2	1.2	13.9 ^{gh}	46.5 ^{fg}	1.4 ^g	.2 ^{gh}	.3 ^g	43.3 ^{gh}	1.9 ^g	52.3 ^{fg}
135	3.0	1.3 ^g	25.3	5.9	1.2	1.2	12.8 ^h	47.7 ^f	1.3 ^g	.2 ^h	.3 ^g	42.2 ^h	1.7 ^g	53.6 ^f
Medium sire growth potential														
A6														
0	6.5 ^f	2.0 ^f	28.9	5.8	1.4 ^f	1.0	15.2 ^g	36.5 ⁱ	1.7 ^f	.6 ^f	.5 ^f	52.0 ^f	2.7 ^f	42.3 ^h
90	3.9 ^g	1.3 ^g	28.9	5.3	1.1 ^g	.8	17.2 ^f	40.0 ^h	1.2 ^g	.2 ^g	.2 ^g	51.0 ^f	1.6 ^g	45.3 ^g
180	3.6 ^{gh}	1.4 ^g	28.4	5.8	1.0 ^g	.9	14.3 ^g	43.0 ^g	1.2 ^g	.2 ^g	.2 ^g	47.3 ^g	1.6 ^g	48.8 ^f
270	3.1 ^h	1.3 ^g	27.2	5.7	.8 ^h	.9	14.1 ^g	45.3 ^f	1.3 ^g	.1 ^g	.2 ^g	45.2 ^g	1.6 ^g	51.0 ^f
A14														
68	2.9 ^g	1.1	25.3	5.0 ^g	1.1 ^g	.8 ^g	17.3 ^f	44.2	1.5	.3 ^f	.5 ^f	46.6	2.4 ^f	49.2
136	3.3 ^f	1.2	25.8	5.3 ^g	1.4 ^f	1.1 ^f	15.0 ^{fg}	45.3	1.4	.1 ^g	.2 ^g	45.5	1.7 ^g	50.6
204	3.4 ^f	1.4	26.1	6.4 ^f	1.1 ^g	1.1 ^f	12.1 ^g	46.7	1.4	.2 ^g	.2 ^g	42.7	1.7 ^g	53.1
A18														
0	3.5	1.4	26.9	5.9	1.4 ^f	1.2	18.1 ^f	38.6 ^h	1.9 ^f	.5 ^f	.4 ^f	50.0 ^f	2.9 ^f	44.5 ^h
45	3.1	1.3	26.7	6.2	1.3 ^g	1.2	14.5 ^g	44.1 ^g	1.2 ^g	.2 ^g	.2 ^g	45.6 ^g	1.7 ^g	50.3 ^g
90	3.1	1.4	26.3	6.3	1.1 ^g	1.2	13.5 ^{fg}	45.5 ^g	1.3 ^g	.2 ^h	.2 ^g	43.9 ^{gh}	1.7 ^g	51.9 ^{fg}
135	3.1	1.3	25.5	6.4	1.1 ^g	1.2	12.5 ^h	47.3 ^f	1.2 ^g	.1 ^h	.2 ^g	42.1 ^h	1.6 ^g	53.7 ^f
SD	.4	.3	1.4	.6	.2	.1	1.8	2.2	.3	.1	.1	2.3	.4	2.3

^aAge when steers entered the feedlot: A6, 6 mo; A12, 12 mo; A18, 18 mo.

^bNumber of days from entering the feedlot

^cTotal saturated fatty acids.

^dTotal polyunsaturated fatty acids.

^eTotal monounsaturated fatty acids.

^{f,g,h,i}Within a sire growth potential and age group, means with different superscripts are different ($P < .05$).

Fatty acids 17:0, 17:1, and 18:3 were not included in analyses because they were not detected or were too low to be quantified.

Except for A12 steers of M sires, 16:0 was not affected by time on feed. In these A12 steers, 16:0 increased ($P = .01$) by 11% from the first to the third slaughter period. For both H- and M-sired steers, 18:0 in LD of A12 and A18 steers decreased ($P = .03$) with time on feed. No effect of time on feed was observed for A6 steers from M sires, but A6 steers from H sires had 18:0 values that first increased ($P = .01$) then decreased to initial values. This difference in sire type and time on feed resulted in an interaction ($P < .01$). Weight percentages of 18:1 were increased ($P < .01$) by time on feed for LM of A6 and A18 steers. The general pattern of change for this fatty acid in LM was the same for either sire type. Weight percentage of 18:2 decreased with time on feed in LM of steers of each growing-finishing strategy and for either sire type.

Weight percentages of total saturated fatty acids were affected little by time on feed in steers of either sire type. For the most part, weight percentages of total polyunsaturated fatty acids decreased with time on feed, and monounsaturated fatty acids increased. Changes in saturated and polyunsaturated fatty acids were affected mainly by changes in 18:0 and 18:2, and 18:1 had the greatest influence on monounsaturated fatty acids.

Overall, only modest changes in total saturated fatty acids were observed in LM with time on feed, which was in contrast to ground carcass total saturated fatty acids. A sire growth potential effect was observed for weight percentage of total saturated fatty acids and indicated a greater value for M (44.5%) than for H (42.8%) steers ($P = .02$). Weight percentage of total polyunsaturated fatty acids tended to be greater in LM of H steers (5.4%) than in LM of M steers (4.7%, $P = .06$). Total monounsaturated fatty

Table 3. Fatty acid weight percentages of total lipids of longissimus muscle dissected free of depot fat

Age group ^a and days to slaughter ^b	14:0	14:1	16:0	16:1	18:0	18:1	18:2	20:4	SAT ^c	PUFA ^d	MUFA ^e
High sire growth potential											
A6											
0	3.1	.8	26.3	9.8	13.9 ^g	37.0 ^h	6.1 ^f	2.9	43.4	9.0 ^f	46.8 ^g
90	2.4	.7	28.5	4.5	15.6 ^f	41.2 ^g	5.1 ^{fg}	2.0	46.5	7.0 ^{fg}	45.7 ^g
180	2.4	.6	26.6	7.6	13.6 ^g	43.6 ^f	3.9 ^g	1.7	42.6	5.6 ^g	51.2 ^f
270	2.5	.7	27.6	5.9	13.1 ^g	45.4 ^f	3.6 ^g	1.2	43.2	4.8 ^g	51.3 ^f
A12											
68	1.9	.5	27.3	4.3	16.1 ^f	43.9	5.5 ^f	.6	45.2	6.1 ^f	48.1
136	2.4	.7	26.8	5.0	14.0 ^{fg}	47.4	3.2 ^g	.6	43.1	3.8 ^g	52.3
204	2.6	.8	27.0	4.7	13.0 ^g	48.5	2.9 ^g	.5	42.6	3.4 ^g	53.3
A18											
0	2.0 ^g	.7	25.9	7.4	15.7 ^f	41.9 ^g	4.8 ^f	1.6	43.6	6.5 ^f	49.3 ^h
45	2.2 ^{fg}	.7	25.7	7.7	13.9 ^{fg}	44.7 ^{fg}	3.6 ^g	1.5	41.8	5.1 ^{fg}	52.4 ^{gh}
90	2.0 ^g	.6	24.2	10.7	12.0 ^g	46.1 ^f	3.2 ^g	1.2	38.3	4.3 ^g	56.8 ^f
135	2.6 ^f	.8	25.5	7.7	12.5 ^g	46.9 ^f	3.0 ^g	1.1	40.6	4.1 ^g	54.6 ^{fg}
Medium sire growth potential											
A6											
0	3.7 ^f	1.0 ^f	26.5	7.3	14.6	38.8 ^g	5.5 ^f	2.7 ^f	44.8	8.2 ^f	46.1
90	2.4 ^g	.5 ^g	27.5	6.6	16.3	41.0 ^g	4.2 ^g	1.5 ^{fg}	46.2	5.7 ^g	47.6
180	2.4 ^g	.6 ^g	27.2	7.1	15.0	43.7 ^f	3.0 ^h	1.0 ^g	44.6	4.1 ^{gh}	50.8
270	2.6 ^g	.7 ^g	28.8	4.4	14.9	45.6 ^f	2.3 ^h	.8 ^g	46.3	3.0 ^h	50.0
A12											
68	1.9 ^g	.5	26.0 ^g	4.0 ^g	17.0 ^f	46.3	3.8	.5	45.0	4.3	50.3
136	2.7 ^f	.7	27.4 ^{fg}	4.3 ^{fg}	15.6 ^{fg}	45.7	3.1	.5	45.7	3.6	50.0
204	3.2 ^f	.7	28.9 ^f	4.9 ^f	13.2 ^g	46.2	2.7	.4	45.2	3.1	51.0
A18											
0	2.1 ^g	.6	26.2	5.9	17.4 ^f	40.3 ^g	5.2 ^f	2.5	45.6 ^f	7.7 ^f	46.2 ^g
45	2.1 ^g	.6	25.0	8.9	13.5 ^g	45.3 ^f	3.3 ^g	1.3	40.5 ^g	4.6 ^g	54.2 ^f
90	2.3 ^{fg}	.7	26.6	6.5	13.4 ^g	46.3 ^f	3.0 ^g	1.2	42.3 ^{fg}	4.2 ^g	52.7 ^g
135	2.6 ^f	.8	27.4	5.4	12.8 ^g	47.3 ^f	2.7 ^g	1.1	42.8 ^{fg}	3.7 ^g	52.7 ^g
SD	.7	.2	2.7	4.2	1.7	2.6	1.2	1.1	4.1	2.1	3.5

^aAge when steers entered the feedlot: A6, 6 mo; A12, 12mo; A18, 18 mo.

^bNumber of days from entering the feedlot.

^cTotal saturated fatty acids.

^dTotal polyunsaturated fatty acids.

^eTotal monounsaturated fatty acids.

^{f,g,h,i}Within a sire growth potential and age group, means with different superscripts are different ($P < .05$).

acids were marginally influenced by time on feed in M steers, but more so in H steers. No sire effect was observed for total monounsaturated fatty acids ($P = .12$).

Fatty Acid Concentration in the Longissimus Muscle. Concentrations of LM fatty acids are shown in Table 4. In essentially all steers, concentrations of all major fatty acids except 18:2 increased with time on feed ($P < .06$). Concentrations of 20:4 were nearly constant with time on feed for steers from either sire type. The increased fatty acid concentrations indicated that muscle-associated lipid increased with time on feed independently of depot fat increases because LM samples were dissected free of visible fat before being analyzed.

Effects of sire growth potential were observed for 16:0 ($P = .02$) and 18:0 ($P < .01$), both of which were greater for steers of M than for those of H sires. Also, total saturated fatty acids were greater ($P = .01$) for M (12.6 mg/g) than for H steers (10.8 mg/g). No effects of sire growth potential were observed for total

polyunsaturated fatty acids ($P = .50$) or monounsaturated fatty acids ($P = .21$).

The nature of changes in major fatty acids observed in the present study have been shown by others. With growth of steers, Rule and Beitz (1986) observed increases in 18:1, 18:2, and 18:3 and decreases in 18:0 in adipose tissue. Concentrations of total fatty acids increased in LM of steers fed high-energy diets more so than in those consuming forage (Miller et al., 1981), but forage-fed cattle typically have greater proportions of polyunsaturated fatty acids, for example 18:3 (Marmer et al., 1984; Miller et al., 1986, 1987).

Of interest in the present study was the potential interaction of sire type with time on feed for steers reared under different nutritional regimens. Subcutaneous adipose tissue of steers sired by Limousin bulls and born from either Angus, Shorthorn, or Hereford cows was higher in 14:0, 16:0, and 16:1 and lower in 18:0 than that of steers sired by Simmental bulls (Gillis and Eskin, 1973). Compared with British

Table 4. Fatty acid concentration (milligrams per gram of fresh muscle) of lipids of longissimus muscle dissected free of depot fat

Age group ^a and days to slaughter ^b	14:0	14:1	16:0	16:1	18:0	18:1	18:2	20:4	SAT ^c	PUFA ^d	MUFA ^e
— High sire growth potential —											
A6											
0	.4 ^g	.1 ^g	2.8 ^h	1.0 ^{fg}	1.5 ^h	4.0 ^h	.6 ^g	.3	4.7 ^h	.9 ^g	5.0 ^h
90	.4 ^g	.1 ^g	4.2 ^{gh}	.7 ^g	2.3 ^{gh}	6.0 ^{gh}	.7 ^g	.3	6.8 ^{gh}	.9 ^g	6.7 ^h
180	.6 ^{fg}	.1 ^g	5.9 ^g	1.7 ^f	3.0 ^{fg}	9.6 ^g	.7 ^g	.3	9.5 ^{fg}	1.0 ^g	11.3 ^g
270	.8 ^f	.2 ^f	8.6 ^f	1.8 ^f	4.1 ^f	14.0 ^f	1.0 ^f	.3	13.5 ^f	1.3 ^f	15.8 ^f
A12											
68	.3 ^h	.1 ^g	3.7 ^h	.6 ^g	2.1 ^g	5.7 ^h	.7 ^g	.1 ^g	6.1 ^h	.8 ^g	6.3 ^h
136	.6 ^g	.2 ^f	7.1 ^g	1.4 ^f	3.7 ^f	12.6 ^g	.8 ^g	.2 ^f	11.4 ^g	1.0 ^g	14.0 ^g
204	1.0 ^f	.3 ^f	9.9 ^f	1.7 ^f	4.8 ^f	17.9 ^f	1.1 ^f	.2 ^f	15.7 ^f	1.2 ^f	19.7 ^f
A18											
0	.5 ^g	.2 ^g	5.8 ^g	1.9	3.4	9.5 ^g	1.0	.4	9.7 ^g	1.3	11.4 ^g
45	.5 ^g	.2 ^g	6.1 ^g	1.8	3.3	10.6 ^g	.8	.3	9.9 ^g	1.2	12.4 ^g
90	.8 ^{fg}	.2 ^{fg}	9.1 ^{fg}	4.5	4.5	17.3 ^f	1.2	.5	14.3 ^{fg}	1.7	21.8 ^f
135	1.1 ^f	.3 ^f	10.8 ^f	3.2	5.4	19.7 ^f	1.1	.4	17.3 ^f	1.5	22.9 ^f
— Medium sire growth potential —											
A6											
0	.5 ^h	.1 ^g	3.4 ^h	.9	1.9 ⁱ	5.0 ^h	.7 ^g	.3	5.7 ^h	1.0	5.8 ^h
90	.5 ^h	.1 ^g	5.2 ^h	1.5	3.1 ^h	8.0 ^h	.8 ^{fg}	.3	8.8 ^h	1.0	9.4 ^h
180	.7 ^g	.2 ^g	8.2 ^g	2.5	4.6 ^g	13.3 ^g	.8 ^{fg}	.3	13.5 ^g	1.1	15.7 ^g
270	1.1 ^f	.3 ^f	12.2 ^f	1.9	6.4 ^f	19.4 ^f	.9 ^f	.3	19.7 ^f	1.2	21.3 ^f
A12											
68	.4 ^g	.1 ^g	5.6 ^g	.9 ^g	3.6 ^g	10.0 ^g	.8	.1	9.6 ^g	.9 ^g	10.8 ^g
136	.9 ^f	.2 ^f	9.2 ^f	1.5 ^f	5.2 ^f	15.3 ^f	1.0	.2	15.4 ^f	1.2 ^f	16.8 ^f
204	1.2 ^f	.3 ^f	11.3 ^f	1.9 ^f	5.2 ^f	18.1 ^f	1.0	.2	17.7 ^f	1.2 ^f	20.0 ^f
A18											
0	.4 ^h	.1 ^h	4.4 ^h	.9	2.9 ^g	6.7 ^h	.8	.3	7.6 ^h	1.1	7.7 ^h
45	.6 ^{gh}	.2 ^{gh}	6.5 ^{gh}	2.5	3.5 ^{fg}	11.8 ^h	.9	.3	10.6 ^{gh}	1.2	14.3 ^g
90	.8 ^{fg}	.2 ^{fg}	8.6 ^{fg}	2.1	4.3 ^{fg}	14.8 ^{fg}	.9	.3	13.7 ^{fg}	1.2	16.9 ^g
135	1.0 ^f	.3 ^h	10.8 ^f	2.1	5.1 ^f	18.5 ^f	.9	.3	16.8 ^f	1.3	20.6 ^f
SD	.3	.1	2.6	1.7	1.3	4.2	.2	.2	4.1	.3	5.2

^aAge when steers entered the feedlot: A6, 6 mo; A12, 12 mo; A18, 18 mo.

^bNumber of days from entering the feedlot.

^cTotal saturated fatty acids.

^dTotal polyunsaturated fatty acids.

^eTotal monosaturated fatty acids.

^{f,g,h,i}Within a sire growth potential and age group, means with different superscripts are different ($P < .05$).

breeds of cattle, American Wagyu cattle had less 16:0 and 18:0 and more 18:1 in adipose tissue and less 18:0 in LM than Angus steers (May et al., 1993). In the present study, steers of H sires tended to have less total saturated and more mono- and polyunsaturated fatty acids in LM, but ground carcass fatty acids were not changed by sire growth potential. Apparently the phenotypic differences observed for growth and carcass fat of steers grown under the sire type \times time on feed \times nutritional factors in this study did not influence the elements necessary to greatly alter fatty acid composition of ground carcass or LM.

Typical ruminant diets are low in fat; dietary fat likely does not contribute as quantitatively to carcass fat deposition during finishing as *de novo* fatty acid biosynthesis. Moreover, lipogenesis is responsible for much of the lipid stored in bovine adipocytes, and this process greatly influences fatty acid composition (Rule et al., 1995). After the steers of the present study

entered the feedlot, weight percentage of 18:2 decreased because this fatty acid was probably diluted by the influx of *de novo* synthesized 16:0, 18:0, and 18:1 during finishing. As a proportion of all fatty acids, 18:0 decreased with time on feed because, as 16:0 was synthesized and elongated to 18:0, desaturation converted the 18:0 to 18:1 (Smith, 1995), which is the major end point of *de novo* fatty acid synthesis in mammals (Rule et al., 1995). Thus, as steers grow and fatten, precise metabolic events dictate the nature of the fatty acids, and unless synthesis, elongation, and desaturation are markedly altered, production of markedly different profiles of fatty acids is not likely. On the other hand, differences in genetics and environment of cattle may cause subtle changes in rates of these processes, as well as possible differences in turnover of specific fatty acids, so that slight differences in fatty acids occur that reflect more or less desirable meat products, as was illustrated in the

present study. The above scenario, however, does not address the influence of diet on fatty acid composition. If desaturase activity alone was greater, the proportion of 14:1 and 16:1 would have been expected to increase along with 18:1. The greatest change in the major fatty acids occurred during the interval between entering the feedlot (the first slaughter period) and the second slaughter. This was the case for 18:0 and 18:3, which decreased, and 18:1, which increased in the ground carcass. The dietary change was from high forage to high concentrate. Adipose tissue of lambs fed diets high in alfalfa pellets had greater weight percentages of 18:0 and 18:3 and lesser weight percentages of 18:1 than those fed high-corn diets (Field et al., 1992).

Ratios of 18:0 to 14:0 + 16:0 (stearate ratio), 18:1 + 18:2 to 14:0 + 16:0 (unsaturated ratio), and 18:0 + 18:1 + 18:2 to 14:0 + 16:0 (combined ratio) are easily calculated from data of Tables 2 and 3. According to the model proposed by Spady et al. (1993), dietary 14:0 and 16:0 cause elevated LDL-cholesterol, whereas 18:0 and 18:2 are neutral, and 18:1 causes reduced LDL-cholesterol, given that cholesterol is consumed with the fatty acids. Thus, as the proportion of 14:0 + 16:0 decreases and proportions of 18:0, 18:1, and 18:2 increase (the ratio increases), the impact of the dietary lipid on LDL-cholesterol levels should be to decrease it. Ground carcass stearate ratios in the present study decreased with time on feed for A12 and A18 steers (.59 to .41), regardless of sire growth potential. Ground carcass of H-sired, A12 and A18 steers had the highest unsaturated and combined ratios (1.75 and 2.21, respectively, compared with 1.67 and 2.13, respectively, for the M-sired steers). Thus, steers sired by H bulls had ground carcasses with the most healthful fatty acid profiles given that the steers were marketed at greater maturity. On the other hand, within each group of steers, total fat and cholesterol of the ground carcass also increased with time on feed. Thus, although unsaturated and combined ratios were optimized with time on feed in A12 and A18 steers, greater total fat also occurred. The oldest A18 steers from H sires had the highest unsaturated (1.80 for H; 1.67 for M) and combined ratios (2.25 for H; 2.10 for M) in the LM. This suggests that lean meat from A18 steers sired by H bulls may have the most healthful ratios of fatty acids with moderate concentrations of cholesterol.

O'Dea et al. (1990) demonstrated that lean beef consumption by healthy individuals was not associated with increased serum cholesterol until beef fat drippings were included in the diet. In rats, a high intake of tallow resulted in lower plasma cholesterol than did vegetable oil until cholesterol intake was increased, which caused increased plasma cholesterol in tallow-fed rats (Rule et al., 1996). Thus, the potential exists for an undesirable interaction between beef fat (or animal fat in general) and dietary cholesterol. The impact that the fat content,

cholesterol concentration, and fatty acid profile of the present study may have on the healthfulness of the meat is difficult to predict. Numerous reports have shown that certain fatty acids may contribute to hypercholesterolemia, whereas others do not. Moreover, as shown by Kritchevsky (1992), feeding fats, such as those containing 16:0, in amounts that reflect typical diets are not necessarily hypercholesterolemic.

In conclusion, no change in LM cholesterol was observed for any of the sire growth potential \times time on feed \times nutritional factors imposed on the steers. Differences in ground carcass cholesterol were likely attributable to differences in fat content. Total saturated fatty acids were lower and total unsaturated fatty acids higher in LM of H than in LM of M steers. This difference led to a greater ratio of 18:0 plus unsaturates to 14:0 + 16:0, especially in A18 steers from H sires. Based on these results, we conclude that cholesterol concentration in muscle is refractory to the sire growth potential \times time on feed \times growing-finishing strategy imposed on steers in this study. Also, fatty acid composition is altered slightly by sire, but mostly by time on feed and nutritional background.

Implications

Sire breeds differing in lean vs fat growth do not interact with nutritional background or feed to affect muscle cholesterol. Fatty acid composition can be modestly changed by this interaction. Steers backgrounded, followed by summer pasturing and then feedlot finishing, produce muscle with optimal ratios of hypocholesterolemic to hypercholesterolemic fatty acids. Thus, by using breeding systems that emphasize lean growth and moderate fat deposition, and a strong backgrounding regimen, beef with lipids that fall well within current health guidelines is readily achievable.

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