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Effect of Breed Type and Sex on the Fatty Acid Composition of Subcutaneous and Intramuscular Lipids of Finishing Steers and Heifers[1]

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ABSTRACT: Effects of breed type and sex on the fatty acid composition of subcutaneous neutral lipid and intramuscular neutral and phospholipids of longissimus lumborum muscle were investigated using 145 steers and 82 heifers that consisted of pure Japanese Black and Holstein and crossbreds among Japanese Black, Holstein, Japanese Brown, and Charolais. Steers and heifers were reared on a high plane of nutrition and were fed the same concentrate diet and rice straw. All animals were slaughtered serially and carcass composition was determined by dissection of the left side of the carcass. Breed type and sex differences of fatty acid percentages of carcass lipids were compared by adjusting the percentages to mean carcass fat percentages. Heifers had higher contents of 18:1 and total monounsaturated fatty acids in subcutaneous and intramuscular neutral lipids than steers ($P < .05$). The fatty acid composition of intramuscular phospholipids differed between sexes for 16:0, 20:1, and 20:5, but the differences were small. Breed differences were significant ($P < .05$) in steers for 16:0, 16:1, 18:1, and total saturated and monounsaturated fatty acids in both subcutaneous and intramuscular neutral lipids, and iso-16:0, 16:0, and total saturated fatty acids in phospholipids, respectively. However, in heifers, fewer fatty acids differed ($P < .05$) among breed types in the neutral lipids. It is suggested that the Japanese Black has a genetic predisposition for producing carcass lipids containing higher concentrations of monounsaturated fatty acids than Holstein, Japanese Brown, or Charolais.

Key Words: Breeds, Sex, Fatty Acids, Carcass Composition

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Introduction

Breed type and sex are major factors that affect fatty acid composition of lipids of carcass dissectible or intramuscular depot fats (Yoshimura and Namikawa, 1983; Eichhorn et al., 1986; Huerta-Leidenz et al., 1993). However, because the fatty acid composition of depot fat is affected by degrees of carcass or body fat deposition itself (Roberts, 1966; Garcia et al., 1979) and there are large differences in fat deposition ability among breed types and sexes (Zembayashi, 1993), an adjustment of fatty acid composition to the same degree of carcass fatness is appropriate to compare the composition among breed types or sexes to avoid the confounding effects of the difference in fatness.

In the present study, the effects of breed type and sex on fatty acid composition of subcutaneous and intramuscular lipids were evaluated by adjusting data for differences in the degree of carcass fatness.

Materials and Methods

Animals and Fattening Method. A total of 145 steers and 82 heifers consisting of two pure- and four crossbred breed types were used. In the steer group, purebred Japanese Black (**B**) and Holstein (**Ho**), and their backcross (BBHo), which were produced by backcrossing F_1 cows (BHo) between Japanese Black bulls and Holstein cows to Japanese Black bulls, were used. Also three-way crosses (RBHo, CBHo) between a Japanese Brown (**R**) or a Charolais (**C**) bull and F_1 cows (BHo) were used. In the heifer group, the purebred B and crossbreeds consisting of BHo, BBHo, RBHo, and CBHo were used. Steers and heifers were fed diets individually in pens attached to Calan broadbent doors (Calan Electronics, Scotland) and

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had the same concentrate diet with 1 kg/d of chopped rice straw available on an ad libitum basis. The concentrate diet consisted of 30% flaked corn, 45% steam-rolled barley, 20% wheat bran, 5% soybean meal, 2 kg of mineral mixture per 100 kg of the concentrate diet, and vitamin additives. The diet contained 12.8 and 73.5% of CP and TDN, respectively. The experiment started at an average animal age of 252 d, except for Ho, which started at the age of 191 d. The cattle were slaughtered serially according to planned live weight intervals so as to cover the same ranges of carcass fatness. Slaughtering started basically from the live weights of 350 to 450 kg and continued by the interval weights of 60 to 70 kg until 650 to 750 kg. Carcass fat content was measured by dissecting the left side of the carcass after more than 24 h of chilling. Kidney knob and channel fat were included in the carcass fat.

Sample Collection. Subcutaneous fat samples were collected at the intersectional location of the anterior end of the 12th rib and the ventral edge of the longissimus thoracis muscle. One-centimeter thicknesses of longissimus lumborum muscle were collected at the location of the anterior end of the fifth lumbar vertebra at the time of dissection. Samples were vacuum-packaged in polyethylene bags and stored at –25°C until fatty acid analysis was completed.

Fatty Acid Analysis. Total lipids were extracted from 2 g of subcutaneous and 10 g of muscle samples using 25 mL and 40 mL of chloroform:methanol (2:1, vol/vol), respectively, after the method of Folch et al. (1957). Two lipid extractions were carried out for the muscle samples. Total lipids, extracted from subcutaneous samples, were methylated without separating into neutral and phospholipids but were categorized as subcutaneous neutral lipid (**SNL**), because the concentration of phospholipids in subcutaneous fat tissue is very low (Christie, 1981). Lipids from muscle samples were separated into intramuscular neutral lipid (**IMNL**) and intramuscular phospholipid (**IMPL**) by the method of Terrell et al. (1968) with some modification. Activated silicic acid (5 g) and 15 mL of lipid extract was shaken vigorously with 50 mL of chloroform for 15 min. The lipid-chloroform-silicic acid mixture was transferred to a sintered-glass filter and washed totally with 150 mL of chloroform to elute the neutral lipid fraction and totally with 120 mL of methanol to elute the phospholipid fraction.

The lipids were methylated with 14% boron trifluoride-methanol by the method of Slover and Lanza (1979). Methylated neutral lipids and phospholipid samples were analyzed using a flame ionization detector on a gas chromatograph (Shimazu GC14A, Kyoto, Japan) equipped with a 50-m × .24-mm capillary column coated with HR-SS-10 and HR-20M, respectively. Film thickness was .25 μm. The column was programmed from 150°C to 220°C at 4C°/min followed by 5 min at 220°C for neutral lipid samples and 170°C to 240°C at 4C°/min followed by 15 min at 240°C for phospholipid samples. The injection port and detector temperatures were maintained at 250°C. The pressures of the gases were 2.2 kg/cm^2 for the carrier gas (helium), .6 kg/cm^2 for the hydrogen, 6 kg/cm^2 for make-up gas (nitrogen), and .5 kg/cm^2 for the combustion air. Split ratio was approximately 1:100. Chromatograms were recorded with a computing integrator (Shimazu Chromatopac C-R6A). Identifications of sample fatty acids were made by comparing the relative retention times of standard fatty acid methyl-esters (Sigma Chemical, St. Louis, MO).

Statistical Analysis of Data. Statistical analysis was done using the GLM procedure of SAS (1988). Fatty acid composition was calculated as area percentages. In addition to individual fatty acid data, the data were summed by the type of fatty acid to obtain total saturated (**SFA**), monounsaturated (**MUFA**), polyunsaturated (**PUFA**), and total unsaturated (**UFA**) fatty acids, and the ratios of MUFA:SFA and PUFA:SFA were calculated. A series of covariate analyses were performed to elucidate sources of variation in the fatty acid composition among sex or breed type by using carcass fat percentage (**CFP**) and, in the case of the analysis for sex effect, slaughter age(day) (**SA**) was added as a covariate. After the tests for parallelism of the regression coefficients (slopes) of linear regression equations among sexes or breed types, the least squares means (**LSM**) of fatty acid percentages at the mean value of the covariate (CFP) was calculated.

Results and Discussion

Means and standard deviations of CFP, slaughter weight (**SW**), and SA by sex and breed type are shown in Table 1. Because it was planned to slaughter both steers and heifers serially to cover a similar range of CFP within each sex, mean SW and SA differed mainly according to the growth potential of the breed types, and larger differences among mean CFP were found between sexes rather than among breed types. However, the standard deviations of total means of both sexes were large enough to compare the LSM of fatty acids among sexes or breed types by testing the parallelisms of the regression coefficients of the equations regressing fatty acid percentages against CFP among sex or breed types.

Comparisons of the LSM for the fatty acid percentages between sexes and the signs and levels of significance of the regression coefficients of the equations regressing the fatty acid percentages against CFP or SA are shown in Table 2. Differences between sexes were found for essentially the same fatty acids of the SNL and IMNL. Heifers had more 18:1, MUFA, and UFA and showed higher ratios of MUFA:SFA and UFA:SFA than steers of the same

Table 1. Means and standard deviations of carcass fat percentage (CFP)[a], slaughter weight (SW), and slaughter age (SA) for steers and heifers

		CFP, %		SW, kg		SA, d	
Sex and breed type[b]	n	Mean	SD[c]	Mean	SD	Mean	SD
Steer							
B	76	28.2	4.58	536.8	89.18	715.3	121.91
Ho	16	27.4	2.97	578.4	75.94	516.3	85.25
B × BHo	32	29.7	5.50	543.1	85.03	601.7	98.73
R × BHo	9	27.3	4.16	536.2	74.60	607.1	103.95
C × BHo	12	27.0	4.97	652.0	107.23	626.8	136.13
Total	145	28.3	4.69	552.3	92.49	654.2	132.53
Heifer							
B	17	35.0	2.68	584.9	70.36	771.7	86.25
BHo	21	33.2	3.23	612.5	72.32	922.0	193.47
B × BHo	30	32.9	5.20	541.5	79.92	683.3	137.46
R × BHo	7	32.0	4.45	530.6	45.43	612.0	59.74
C × BHo	7	35.0	3.59	719.1	47.26	901.9	122.10
Total	82	33.5	4.14	582.9	87.05	775.3	184.82

[a]Kidney knob and channel fat were included.
[b]B = Japanese Black; Ho = Holstein; BHo = F_1 between Japanese Black bulls and Holstein cows; B × BHo, R × BHo, and C × BHo = crossbreds among Japanese Black, Japanese Brown and Charolais bulls and BHo cows, respectively.
[c]Standard deviation.

CFP in SNL and IMNL and also had more 15:0 and 18:3 in SNL ($P < .05$). The reverse was true for 14:0, 14:1, 16:0, 16:1, and SFA in SNL and IMNL, and for 18:2 in SNL ($P < .05$). These results suggest that the fatty acid composition of the neutral lipid of subcutaneous and intramuscular fat is affected by sex and is independent of the degree of carcass fat deposition.

Terrell et al. (1968), Marchello et al. (1970), Terrell et al. (1969), and Waldman et al. (1968) reported results on the influence of sex on fatty acid composition of subcutaneous and intermuscular neural lipid, in that heifers had higher percentages of 18:1 and lower percentages of 14:0, 16:0, and 18:0 than steers. These results were similar to the present results, except for 18:0.

In Table 3, the LSM of fatty acid percentages were compared at the same CFP (steer:28.0%, heifer: 33.5%) between SNL and IMNL by sex. Subcutaneous neutral lipid had more 14:1, 15:0, 16:1, and 17:1 than IMNL in both sexes and had more 18:2 in steers ($P < .05$). The reverse was true for 17:0 and 20:1 in both sexes and for 18:0 and 18:1 in heifers ($P < .05$). However, none of SFA, MUFA, PUFA, or UFA, nor the ratios of MUFA, PUFA, and UFA to SFA differed between SNL and IMNL in the sexes, except for PUFA in steers ($P < .05$). Sturdivant et al. (1992) reported that subcutaneous adipose tissue had more 14:1 and 16:1 and less 18:0 and 18:2 compared with intramuscular adipose tissues ($P < .05$). They also did not find differences in the MUFA:SFA ratio across tissues. The present results, except for 18:0 in steers and 18:2 in both sexes, were similar to the results of Sturdivant et al. (1992), although the effect of carcass fatness was removed in our study.

In spite of the LSM of SFA, MUFA and UFA did not differ between SNL and IMNL in the sexes, and the LSM of 18:0 and 18:1 in heifer SNL and IMNL, respectively, were inversely related to those of 14:1 and 16:1. The biological significance of the differences of individual fatty acid percentages between SNL and IMNL remains to be demonstrated.

In Table 2, the percentages of 14:0, 14:1, 16:1 and 20:5 of IMPL were higher in heifers than in steers. The reverse was true for 20:1. However, the differences of the values between sexes were small. The concentrations of MUFA and PUFA in IMPL were inclined to be inversely related to those in SNL and IMNL. These results were similar to the results of Hornstein et al. (1961) and Larick et al. (1989).

Terrell et al. (1968), in cattle, and Allen et al. (1967), in pigs reported that sex effects were totally associated with the neutral fraction fatty acids rather than the phospholipid fraction fatty acids. Present results support their results that sex effects on major fatty acid composition of neutral lipids were significant ($P < .05$) but were not significant for those of phospholipids ($P > .05$). Prior et al. (1983) reported that the manipulation of sex hormone status of living cattle influenced lipid metabolism in the adipose tissue, and sex differences in the fatty acid composition are known to be associated with hormonal changes and their possible influence on enzymatic systems. However, cellular mechanisms for this relationship are, especially in ruminants, not fully understood (Vernon, 1986).

The signs of the significant regression coefficients of the equations regressing MUFA and UFA percentages against CFP or SA were positive in both SNL and IMPL (Table 2). These results suggest that those fatty acid percentages in SNL and IMPL increased generally with the increment of CFP or SA. In the case of IMNL, none of the coefficients for SFA, MUFA,

Table 2. Comparison of the least squares means[a] of fatty acid percentages in subcutaneous and intramuscular lipids between steer and heifer and signs and significant levels of the linear regression coefficients of the equation regressing the fatty acid percentages to carcass fat percentage or slaughter age

	SNL[c]				IMNL[c]				IMPL[c]			
Fatty acid[b]	Steer	Heifer	C-CFP[d]	C-SA[d]	Steer	Heifer	C-CFP	C-SA	Steer	Heifer	C-CFP	C-SA
14:0	3.3^{y}	2.7^{x}	–***	–***	2.7^{y}	2.1^{x}	+***	$-^{ns}$	$.4^{y}$	$.6^{x}$	$+^{ns}$	$-^{ns}$
14:1	2.0^{y}	1.7^{x}	+***	+**	$.9^{y}$	$.8^{x}$	+***	+***	$.05^{y}$	$.08^{x}$	$-^{ns}$	$-^{ns}$
15:0	$.21^{x}$	$.23^{y}$	–**	+**	.13	.13	$-^{ns}$	$+^{ns}$	—	—		
iso-16:0	—	—			—	—			7.9	8.1	$-^{ns}$I	$+^{ns}$
16:0	26.0^{y}	23.5^{x}	–**	–***	24.8^{y}	20.9^{x}	+***	$-^{ns}$	13.0	13.5	$-^{ns}$I	–***I
16:1	7.0^{y}	6.6^{x}	+***	+***	4.4^{y}	4.0^{x}	+***	+***	2.6^{y}	3.0^{x}	$+^{ns}$	$+^{ns}$
17:0	1.1	1.0	–***	–***	1.4	1.3	$-^{ns}$	–**	5.0	4.7	$-^{ns}$	$+^{ns}$
17:1	1.7	1.7	$+^{ns}$	+***	1.5	1.4	$+^{ns}$	$-^{ns}$	2.0	5.5	$+^{ns}$	$-^{ns}$
18:0	7.9	7.5	–***I[e]	–***	10.2	9.6	–***	–***I	8.8	9.0	$+^{ns}$	$-^{ns}$
18:1	46.3^{x}	51.1^{y}	+***	+***	49.4^{x}	55.0^{y}	–*	$+^{ns}$	19.7	18.6	+***	$+^{ns}$
18:2	2.6^{y}	1.9^{x}	$-^{ns}$	$+^{ns}$	2.2	2.0	$-^{ns}$	$-^{ns}$	21.3	22.2	$-^{ns}$	$+^{ns}$
19:0	—	—			—	—			.7	.5	$-^{ns}$	$-^{ns}$
18:3	$.67^{x}$	$.90^{y}$	–*	+*	.68	.92	$-^{ns}$	$+^{ns}$	1.9	2.1	$-^{ns}$	$-^{ns}$
20:0	—	—			—	—			.8	.6	$-^{ns}$	$+^{ns}$
20:1	1.2	1.2	$+^{ns}$	+***	1.6	2.0	$+^{ns}$	$+^{ns}$	$.9^{y}$	$.5^{x}$	$+^{ns}$	$+^{ns}$
20:2	—	—			—	—			.6	.4	$-^{ns}$	$-^{ns}$
21:0	—	—			—	—			3.0	2.9	$+^{ns}$	+*
20:3	—	—			—	—			9.4	9.2	–***	$-^{ns}$
20:4	—	—			—	—			.12	.04	$+^{ns}$	$+^{ns}$
20:5	—	—			—	—			1.0^{x}	1.5^{y}	–**	$-^{ns}$
22:0	—	—			—	—			.8	.4	$+^{ns}$	$+^{ns}$
22:1	—	—			—	—			.03	.03	$-^{ns}$	$-^{ns}$
SFA	38.5^{y}	35.0^{x}	–***	–***	39.3^{y}	34.0^{x}	$+^{ns}$	–**	40.3	40.4	$+^{ns}$	$-^{ns}$
MUFA	58.2^{x}	62.2^{y}	+***	+***	57.8^{x}	63.1^{y}	$-^{ns}$	+*	25.3	24.2	+***	$+^{ns}$
PUFA	3.3	2.8	$-^{ns}$	$+^{ns}$	2.9	2.9	$-^{ns}$	$+^{ns}$	34.4	35.4	–**	$-^{ns}$
UFA	61.5^{x}	65.1^{y}	+***	+***	60.7^{x}	66.0^{y}	$-^{ns}$	+**	59.7	59.6	$-^{ns}$	$+^{ns}$
MUFA:SFA	1.56^{x}	1.88^{y}	+***	+***	1.53^{x}	1.91^{y}	$-^{ns}$	+**	.63	.60	+***	$+^{ns}$
PUFA:SFA	.09	.08	$+^{ns}$	+***	.08	.08	$-^{ns}$	$+^{ns}$	.87	.89	$-^{ns}$	$-^{ns}$
UFA:SFA	1.64^{x}	1.96^{y}	+***	+***	1.60^{x}	1.99^{y}	$-^{ns}$	+**	1.49	1.49	$-^{ns}$	$+^{ns}$

[a]Values at mean carcass fat percentage of 29.8%.
[b]SFA = total saturated fatty acids; MUFA = total monounsaturated fatty acids; PUFA = total polyunsaturated fatty acids; UFA = total unsaturated fatty acids.
[c]SNL = subcutaneous neutral lipid; IMNL = intramuscular neutral lipid; IMPL = intramuscular phospholipids.
[d]Signs (+,–) and significant levels of the linear regression coefficients of the regression equations regressing fatty acid percentages to carcass fat percentage (CFP) or slaughter age (SA). *$P < .05$, **$P < .01$, ***$P < .001$. ns = nonsignificant.
[e]I = the linear regression coefficients differed significantly between sex.
[x,y]Means with different superscripts within the same rows and lipids differ at $P < .05$.

PUFA, or UFA were significant ($P > .05$). However, when these total fatty acids were regressed to SA, the coefficients for SFA, MUFA, and UFA became significant ($P < .05$) and the signs of MUFA and UFA were positive. These results suggest that MUFA or UFA percentage in IMNL correlated better with SA than with CFP. Zembayashi (1994) investigated the factors that affect the deposition of intramuscular lipid in the same breed types used in the present study and reported that the intramuscular lipid deposition correlated better with SA than with CFP. Consequently, the fatty acid composition of IMNL correlated better with the amount of intramuscular lipid than with CFP.

It is reported that bovine longissimus muscle with a high percentage of oleate (18:1) or unsaturated fatty acid generally scored higher in taste panel evaluations (Westerling and Hedrick, 1979; Dryden and Marchello, 1970) and the consumption of diets high in unsaturated fatty acid, especially polyunsaturated fatty acid, is good for human health (Sinclair and O'dea, 1990). These reports support the conclusion that heifer meat is more desirable than steer meat as far as the fatty acid composition of carcass lipids is concerned.

The LSM for the major fatty acids in SNL, IMNL, and IMPL at common CFP, significance levels of differences of the means, and regression coefficients among breed types are shown by sex in Tables 4, 5, and 6, respectively.

As for the fatty acid composition of steer neutral lipids, the LSM of 18:1, MUFA, and MUFA:SFA ratio in SNL (Table 4) were greater in B, BBHo, and CBHo than in Ho ($P < .05$). Those of MUFA and MUFA:SFA in IMNL (Table 5) were greater in B and BBHo than in the other breed types ($P < .05$). These results suggest that B has a genetic predisposition for depositing MUFA in these lipids.

Table 3. Comparison of the least squares means[a] of fatty acid percentages between subcutaneous (SNL) and intramuscular (IMNL) neutral lipids by sex

Fatty acid	Steer			Heifer		
	SNL	IMNL	P[b]	SNL	IMNL	P
14:0	3.4	2.7	***I[c]	2.7	2.3	***I
14:1	2.0	.9	***	1.8	.9	***
15:0	.22	.14	***	.22	.12	***
16:0	26.2	24.4	***I	23.0	21.6	*I
16:1	6.8	4.2	***	6.9	4.3	***
17:0	1.2	1.4	***	1.0	1.3	***
17:1	1.7	1.5	***	1.7	1.4	***
18:0	8.4	10.5	***I	6.7	9.1	***
18:1	45.8	49.9	***I	52.0	54.2	*
18:2	2.6	2.2	**	1.9	1.9	ns
18:3	.72	.69	ns	.82	.89	ns
20:1	1.1	1.6	***	1.2	2.0	***
SFA	39.3	39.1	ns	33.6	34.4	ns
MUFA	57.4	58.0	ns	63.6	62.8	ns
PUFA	3.3	2.9	*	2.8	2.8	ns
UFA	60.7	60.9	ns	66.4	65.6	ns
MUFA:SFA	1.50	1.55	ns	1.97	1.88	ns
PUFA:SFA	.09	.08	ns	.08	.08	ns
UFA:SFA	1.59	1.62	ns	2.05	1.96	ns

[a]Values at mean carcass fat percentages of steers (28.0%) and heifers (33.5%).
[b]*P < .05, **P < .01, ***P < .001. ns = nonsignificant.
[c]I = the linear regression coefficients of the equations regressing fatty acid percentages against carcass fat percentage differed significantly (P < .05) between SNL and IMNL.

Table 4. Comparisons of the least squares means[a] of the percentages of major fatty acids in subcutaneous neutral lipid (SNL) among breed types

Sex and breed type[b]	14:0	16:0	16:1	18:0	18:1	18:2	SFA[c]	MUFA[b]	MUFA:SFA
Steer									
B	3.2^{y}	25.2^{y}	7.1^{z}	7.9^{x}	46.3^{z}	2.7^{z}	37.4^{x}	58.9^{z}	1.61^{z}
Ho	4.2^{z}	29.7^{z}	6.1^{xy}	9.7^{z}	41.6^{y}	2.7^{z}	44.9^{z}	52.0^{x}	1.17^{x}
B × BHo	3.1^{y}	25.7^{y}	6.4^{xy}	8.3^{xy}	47.3^{z}	2.5^{z}	38.4^{x}	58.5^{z}	1.57^{z}
R × BHo	3.3^{y}	28.3^{z}	6.2^{xy}	9.1^{yz}	45.0^{yz}	2.7^{z}	41.9^{yz}	55.3^{xy}	1.33^{xy}
C × BHo	3.5^{y}	28.2^{z}	7.0^{yz}	8.5^{xz}	45.1^{z}	1.9^{y}	41.4^{y}	56.6^{yz}	1.39^{yz}
Significance of difference among breed types[d]									
Means	***	***	**	**	***	***	***	***	***
C[e]	ns	ns	ns	ns	ns	ns	ns	ns	ns
Heifer									
B	2.5	21.3^{x}	6.5	6.5^{y}	54.0	1.6	31.2^{y}	66.4^{z}	2.24^{z}
BHo	2.6	22.2^{xy}	7.1	6.6^{y}	51.5	2.1	32.4^{y}	64.6^{z}	2.05^{yz}
B × BHo	2.7	23.3^{xy}	6.8	6.7^{y}	50.8	2.1	33.6^{y}	63.3^{yz}	1.94^{xy}
R × BHo	3.0	26.6^{z}	6.2	8.5^{z}	48.0	1.7	39.0^{z}	58.8^{y}	1.55^{x}
C × BHo	2.8	25.1^{yz}	7.9	6.3^{y}	49.5	1.6	35.1^{y}	63.1^{yz}	1.84^{xz}
Significance of difference among breed types[d]									
Means	—[f]	**	ns	**	ns	ns	*	*	*
C[e]	*	ns	ns	ns	ns	ns	ns	ns	ns

[a]Values at the mean carcass fat percentages of steers (27.7%) or heifers (33.5%).
[b]B = Japanese Black; Ho = Holstein; BHo = F_1 between Japanese Black bulls and Holstein cows; B × BHo, R × BHo and C × BHo = crossbreds among Japanese Black, Japanese Brown, and Charolais bulls and BHo cows, respectively.
[c]SFA = total saturated fatty acids; MUFA = total monounsaturated fatty acids.
[d]*P < .05; **P < .01, ***P < .001. ns = nonsignificant.
[e]C = the linear regression coefficients of the regression equations regressing fatty acid percentages to carcass fat percentage.
[f]Comparisons of means among breed types were not applicable.
[x,y,z]Means with different superscripts within same sex and column differ significantly at P < .05.

Table 5. Comparisons of the least squares means[a] of the percentage of major fatty acids in intramuscular neutral lipid (IMNL) among breed types

Sex and breed type[b]	14:0	16:0	16:1	18:0	18:1	18:2	SFA[c]	MUFA[c]	MUFA:SFA
Steer									
B	2.6^{y}	23.1^{y}	4.2^{yz}	9.9	51.2^{z}	2.2	37.0^{y}	59.9^{z}	1.69^{z}
Ho	3.5^{z}	28.5^{z}	4.6^{z}	10.9	44.9^{x}	2.4	44.3^{z}	53.0^{y}	1.20^{y}
B × BHo	2.5^{y}	23.2^{y}	4.1^{y}	10.4	51.1^{yz}	2.3	37.5^{y}	59.6^{z}	1.65^{z}
R × BHo	2.4^{y}	26.8^{z}	3.8^{y}	12.5	47.8^{xz}	2.5	42.9^{z}	54.3^{y}	1.27^{y}
C × BHo	2.7^{y}	27.6^{z}	4.0^{y}	12.5	46.7^{xy}	1.9	44.2^{z}	53.7^{y}	1.22^{y}
Significance of difference among breeds[d]									
Means	***	***	*	—[f]	**	ns	***	***	***
C[e]	ns	ns	ns	*	ns	ns	ns	ns	ns
Heifer									
B	2.2	21.2	4.2^{z}	8.9	55.7	1.6	33.5	64.2	1.96
BHo	2.3	21.2	4.4^{z}	9.1	54.5	1.9	33.9	63.1	1.91
B × BHo	2.3	21.9	4.3^{z}	9.1	53.5	2.1	34.6	62.4	1.88
R × BHo	2.2	22.4	3.6^{y}	9.8	55.6	1.3	35.6	62.5	1.77
C × BHo	2.2	22.3	4.8^{z}	9.0	50.4	2.9	34.8	61.3	1.79
Significance of difference among breeds[d]									
Means	ns	ns	*	ns	ns	ns	ns	ns	ns
C[e]	ns	ns	ns	ns	ns	ns	ns	ns	ns

[a]Values at the mean carcass fat percentages of steers (27.7%) or heifers (33.5%).
[b]B = Japanese Black; Ho = Holstein; BHo = F_1 between Japanese Black bulls and Holstein cows; B × BHo, R × BHo, and C × BHo = crossbreds among Japanese Black, Japanese Brown, and Charolais bulls and BHo cows, respectively.
[c]SFA = total saturated fatty acids; MUFA = total monounsaturated fatty acids.
[d]*P < .05, **P < .01, ***P < .001. ns = nonsignificant.
[e]C = the regression coefficients of linear regression equations regressing fatty acid percentage to carcass fat percentage.
[f]Comparisons of means among breed types were not applicable.
[x,y,z]Means with different superscripts within same sex and column differ significantly at P < .05.

Table 6. Comparisons of the least squares means[a] of the percentages of major fatty acids in intramuscular phospholipids (IMPL) among breed types

Sex and breed type[b]	iso-16:0	16:0	18:0	18:1	18:2	20:3	SFA[c]	MUFA[c]	PUFA[c]	MUFA: SFA	PUFA: SFA
Steer											
B	8.0^{yz}	12.4^{y}	8.8	19.0	21.5	9.6	40.2	24.4	35.4	.60	.89
Ho	7.1^{x}	14.0^{z}	9.0	19.0	20.1	9.3	40.5	25.9	33.6	.64	.83
B × BHo	8.2^{z}	13.8^{z}	8.6	19.7	21.0	9.9	41.1	25.2	36.7	.61	.83
R × BHo	7.1^{xy}	13.6^{z}	9.2	19.2	23.4	10.3	38.8	25.0	36.2	.65	.95
C × BHo	7.4^{yz}	13.0^{yz}	8.3	20.3	22.0	9.1	39.2	25.9	34.9	.67	.90
Significances of difference among breeds[d]											
Means	*	***	ns	ns	ns	ns	ns	ns	ns	ns	ns
C[e]	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Heifer											
B	7.5^{y}	13.4	8.7	20.7	22.1^{yz}	8.4^{x}	39.1^{y}	26.3	34.7^{yz}	$.68^{z}$	$.90^{yz}$
BHo	8.4^{yz}	13.8	9.2	19.9	20.4^{x}	8.5^{xy}	41.2^{z}	26.2	32.7^{y}	$.64^{z}$	$.80^{y}$
B × BHo	8.8^{z}	13.3	9.2	18.2	23.5^{z}	9.2^{yz}	40.9^{z}	23.2	35.9^{z}	$.57^{y}$	$.89^{yz}$
R × BHo	7.5^{y}	14.0	8.7	20.5	18.3^{x}	8.6^{xy}	41.7^{z}	26.3	32.0^{y}	$.63^{yz}$	$.77^{y}$
C × BHo	7.5^{yz}	12.7	8.5	18.3	24.1^{yz}	10.2^{z}	38.4^{y}	23.5	38.1^{z}	$.62^{yz}$	1.01^{z}
Significances of difference among breeds[d]											
Means	*	ns	ns	—[f]	*	*	*	—[f]	*	**	*
C[e]	ns	ns	ns	*	ns	ns	ns	*	ns	ns	ns

[a]Values at the mean carcass fat percentages of steers (27.7%) or heifers (33.5%).
[b]B = Japanese Black; Ho = Holstein; BHo = F_1 between Japanese Black bulls and Holstein cows; B × BHo, R × BHo, and C × BHo = crossbreds among Japanese Black, Japanese Brown, and Charolais bulls and BHo cows, respectively.
[c]SFA = total saturated fatty acids; MUFA = total monounsaturated fatty acids. PUFA = total polyunsaturated fatty acids.
[d]*P < .05, **P < .01, ***P < .001. ns = nonsignificant.
[e]C = the regression coefficients of linear regression equations regressing fatty acid percentage to carcass fat percentage.
[f]Comparisons of means among breed-types were not applicable.
[x,y,z]Means with different superscripts within same sex and column differ significantly at P < .05.

In heifers, the LSM of 14:0, 16:1, 18:1, and 18:2 in SNL, and all of the major fatty acids listed in Table 5 except for 16:1, did not differ among breed types ($P > .05$). The MUFA and MUFA:SFA ratio for RBHo in SNL were less than those of B and BHo ($P < .05$), and those values for B were the highest.

In Table 6, the results for IMPL are shown. In steers, the LSM of iso-16:0 and 16:0, and in heifers, iso-16:0, 18:2, 20:3, SFA, PUFA, MUFA:SFA, and PUFA:SFA differed among breed types. However, the differences among breed types were rather small in both sexes. It seemed to be difficult to find biological meaning for the differences in the values among breed types as found in the results for the fatty acid composition of neutral lipids.

Yoshimura and Namikawa (1983) investigated the fatty acid composition of the subcutaneous triglycerides of several breeds and reported that Japanese Black had the highest percentage of 18:1 and UFA, whereas Holstein had the lowest and the F_1 between Japanese Black and Holstein (BHo) was intermediate. Their results were similar to ours. Gillis and Eskin (1973) also reported significant breed effects and sire and dam interactions on the fatty acid composition of subcutaneous lipid. Eichhorn et al. (1986) investigated the fatty acid composition of adipose tissue using 15 purebred and crossbred cows and reported differences for almost all the fatty acids found in subcutaneous fat among breeds.

The MUFA:SFA ratios of SNL of Japanese Black (1.61 in steers and 2.24 in heifers) were inclined to be greater than the reported values for other breeds: 1.54 for Hereford cows (Huerta-Leidenz et al., 1993), 1.04 for Angus-Hereford-cross steers (St. John et al., 1987), and 1.17 for Angus steers (May et al., 1993). Concerning the greater MUFA deposition in fatty tissues of Wagyu (Japanese Black) cattle, Sturdivant et al. (1992) postulated that elevated stearoyl-CoA desaturase activity could be responsible for the elevated MUFA observed in Wagyu cattle adipose tissue. Myristate (14:0), palmitate (16:0), and stearate (18:0) are desaturated by stearoyl-CoA desaturase to their corresponding *n*-9 MUFA. In the present steer results, the differences of the LSM among breed types for 18:1 or MUFA in neutral lipids seemed to be inversely related to those of 16:0 rather than to those of 14:0 or 18:0.

Sturdivant et al. (1992) obtained a conflicting result about a genetic predisposition for MUFA deposition of Wagyu cattle. The MUFA values of Wagyu × Angus crossbred cattle were essentially identical to those reported for purebred Angus steers (Sweeten et al., 1990). The results of the present study would support the conclusion that Japanese Black has a genetic predisposition for synthesis and deposition of 18:1 or MUFA in SNL and IMNL. Zembayashi and Nishimura (unpublished data) found that the difference of genetic predisposition for 18:1 or MUFA deposition exists even among the breeding bulls of Japanese Black. The conflicting results on this trait of Wagyu cattle obtained by Sturdivant et al. (1992) may be due to the genetic variations on the trait among Japanese Black bulls.

It is considered that lipids containing higher levels of MUFA or UFA are effective in making carcass fat softer and improving meat quality, especially meat texture. A genetic approach may be useful to improve fatty acid composition of carcass tissue lipids. Present results indicate that the Japanese Black breed has the potential for producing higher MUFA content in beef without increasing carcass fat levels.

Implications

Differences in fatty acid composition between breed types and sexes were observed after composition data were adjusted for carcass fat percentage. This finding suggests that fatty acid compositional differences among breed types or across sexes were not caused by differences in carcass fatness or animal age. This information is especially useful because Japanese Black cattle may be used for the genetic improvement of fatty acid composition of beef carcass tissue lipids without increasing carcass fatness. Also, this information is useful for interpreting the reported differences in fatty acid composition of Japanese Black cattle; these animals typically are older and fatter than cattle raised in the United States.

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