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STEAROYL COENZYME A DESATURASE GENE EXPRESSION MEDIATES FATTY ACID COMPOSITION OF ADIPOSE TISSUE FROM ANGUS AND WAGYU STEERS FED TO U.S. AND JAPANESE ENDPOINTS

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Introduction

Zembayashi (1994) demonstrated that totally trimmed *M. longissimus lumborum* of Japanese Black (Wagyu) cattle fed in Japan may contain as much as 20% extractable lipid. A subsequent report from this laboratory showed that the *M. longissimus dorsi* from Wagyu steers fed a corn and barley-based diet for 552 d contained nearly 19% extractable lipid, even though the steers were a mixture of 3/4 and 7/8 crossbred Wagyu steers (Lunt *et al.*, 1993). *M. longissimus dorsi* of Angus steers fed the same diet for the same period of time contained 14.5% extractable lipid. Although USDA quality grades did not differ between the Angus and Wagyu steers of the previous study (Prime^{19} vs Prime^{48}, respectively), the Wagyu steers had a greater beef marbling score (7.30 vs 4.50) and quality grade (4.40 vs 3.40) than the Angus steers, based on the Japanese grading system. Although Japanese Black and American Wagyu steers produce carcasses with higher quality grades than Angus steers when fed to a typical Japanese endpoint (650 kg), it is less clear whether Japanese cattle will produce higher quality carcasses if fed to a typical U.S. live weight endpoint. Japanese Black cattle fed in Japan typically are fed diets low in concentrate and high in fiber, but the concentration of intramuscular lipid (IML) in the *M. longissimus thoracis* appears to increase throughout their extended feeding periods (Zembayashi *et al.*, 1995). It is not known if Angus steers can deposit intramuscular lipid throughout extended feeding or if they can produce high quality carcasses if fed high roughage diets for extended periods.

Meat from Wagyu cattle is characterized by a higher amount of monounsaturated fatty acid (MUFA) in adipose tissues than is observed in adipose tissue of breed types typically produced in the U.S. (Sturdivant *et al*.,1992). An early investigation (Cameron *et al*., 1994) indicated no difference in subcutaneous (s.c.) adipose tissue stearoyl coenzyme A desaturase (SCD) enzyme activity or gene expression between Angus and American Wagyu cattle fed to the Japanese endpoint, in spite of significantly greater MUFA in Wagyu adipose tissue. We hypothesized that differences in fatty acid composition between Wagyu and Angus cattle may be been due to greater SCD activity over the feeding period, which would have resulted in increased MUFA deposition at some point before slaughter. Therefore, we compared Angus and Wagyu cattle fed a corn-based finishing diet or a hay-based diet to 525 kg (U.S. endpoint) or 650 kg (Japanese endpoint).

Objectives

We hypothesized that USDA quality grades of Angus and Wagyu steers would not differ if the steers were fed to a typical U.S. endpoint (approximately 525 kg), but that Wagyu steers would have greater quality grades than Angus steers when fed to a Japanese endpoint (650 kg). We hypothesized that differences in fatty acid composition between Wagyu and Angus cattle are due to greater SCD activity earlier in production.

Methodology

Animal and Diets: Sixteen Wagyu crossbred (7/8 Wagyu or higher) and 16 Angus steers were purchased as calves at weaning (approximately 8 mo of age). The diet was designed to achieve an average gain of 1.36 kg/d, and was fed free choice for 8 or 16 mo after weaning (n = 4 per breed and time on feed). The remaining 8 steers of each breed type were offered coastal bermuda grass hay free choice, supplemented with non-protein nitrogen, and fed daily an amount of the corn-based diet estimated to achieve a targeted rate of gain of 0.9 kg/d. The hay-fed steers were fed for 12 or 20 mo after weaning (n = 4 per breed and time on feed). Targeted final body weights were 525 kg for steers fed for either 8 mo on corn or 12 mo on the hay-based diet, and were 650 kg for steers fed for either 16 mo on corn or 20 mo on the hay-based diet. After being fed for their respective time periods, the steers in each group were slaughtered on two consecutive days. The 5^{th}-8^{th} thoracic rib section of the *M. longissimus thoracis* an overlying fat was removed immediately after hide removal.

Carcass Characteristics: Carcasses were chilled at 4°C for 48 h and quality and yield grade factors were evaluated by trained personnel (USDA, 1997). USDA quality grade factors include overall maturity score and marbling score, whereas USDA yield grade was calculated based on adjusted fat thickness, *M. longissimus dorsi* cross-sectional (ribeye) area, carcass weight, and percentage of kidney, pelvic, and heart fat.

Fats and Moistures: *A* 100-g portion of the *M. longissimus thoracis*, completely trimmed of s.c. adipose tissue, was homogenized. Fat and moisture content were determined by standard methods (AOAC, 1990).

Total Lipid Extraction: Total lipid was extracted from muscle and s.c. adipose tissue by a modification of the methods of Folch *et al*. (1957).

SCD Enzyme Activity and Gene Expression: The activity of SCD enzyme activity was determined as described by St. John *et al*. (1991). SCD RNA was measured by Northern blot analysis using SCD RNA probes.

Fatty Acid Composition Analysis: Fatty acid methyl esters (FAME) of s.c. adipose tissue were analyzed using a Varian gas chromatograph (model CP-3800) by the method of Smith *et al*. (2002).

Statistical Analyses: Data were analyzed using the GLM as a two-factor design with the SAS version 8.1 (SAS Inst. Inc., Cary, NC). Means were compared by three-factor ANOVA. Main effects were breed type, diet, and endpoint (U.S. or Japanese), and the model tested all 2- and 3- way interactions. Interaction means were separated using the probability statement of GLM in the significant difference ($P < 0.05$).

Results & Discussion

Marbling scores and USDA quality grades were not different between breed types (*P* ≥ 0.30; Table 1). However, most of the carcasses in the 16-mo and 20-mo groups were up into the USDA prime grade. Under the USDA grading system, it is difficult to discern differences between such highly marbled carcasses.

The interaction between breed and time-on-feed was significant for IML% of the *M. longissimus thoracis* (*P* < 0.03); the Wagyu carcasses in the 20-mo group contained more than 20% IML as compared to 12% for the Angus at the same endpoint. Intramuscular lipid increased in Angus steers until 16 mo on feed and did not increase thereafter. In contrast, IML continued to increase in the Wagyu cattle until the end of the study.

There was sufficiently greater s.c. fat thickness in the Angus steers (*P* = 0.01) to cause a significant difference in yield grade (*P* = 0.01; Table 1). Endpoint also had a significant effect on ribeye area, adjusted fat thickness, and USDA yield grade (*P* = 0.01). The higher yield grade of the Angus steers indicates the greater carcass adiposity of this breed type, compared to Wagyu steers (Zembayashi, 1994).

Wagyu contained a lower (*P* < 0.01) percentage of palmitate than Angus at all slaughtering time. Palmitoleate (16:1) was increased (*P* < 0.01) in s.c. adipose tissue when steers were finished to the Japanese endpoint compared to those finished to the U.S. endpoint. Stearate (18:0) remarkably (*P* < 0.01) decreased in Japanese endpoint steers compared with U.S. endpoint steers, and oleate (18:1) percentages were greater (*P* < 0.01) in Japanese endpoint steers than in U.S. endpoint steers. Wagyu steers had higher (*P* < 0.03) concentrations of oleate than Angus steers. The sum of MUFA in steers fed to the Japanese endpoint increased significantly (*P* < 0.01) compared to MUFA in steers fed to the U.S. endpoint.

SCD enzyme activity was not affected by breed type (*P* = 1.00) or diet (*P* = 0.40; Table 2), but was higher (*P* = 0.01) in Japanese endpoint steers than in U.S. endpoint steers. The diet x endpoint interaction (*P* = 0.08) suggested that SCD activity was greater in hay-fed cattle than corn-fed cattle, but only at the U.S. endpoint. The pattern of SCD gene expression was similar to that for enzyme activity (Table 2). Also, the significant breed x endpoint interaction indicated that Angus steers had peak expression at the U.S. endpoint, whereas SCD gene expression was highest at the Japanese endpoint for Wagyu steers. The pattern SCD enzyme activity and gene expression were similar to changes in fatty acid composition (Table 2). Waldman *et al*. (1968) and Huerta-Leidenz *et al*. (1996) previously indicated that concentration of MUFA increases in s.c. adipose tissue of U.S. cattle with age and carcass weight. Certainly, the age of the Wagyu and Angus steers affected MUFA concentrations in the cattle of this study.

Conclusions

We conclude that Wagyu cattle should be fed a high roughage diet for a relatively lengthy feeding period in order to reach their genetic potential to deposit maximum levels of marbling. This investigation showed no differences in SCD gene expression between Wagyu and Angus steers, but SCD activity peaked earlier in Angus steers than in Wagyu steers.

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Tables and Figures

Table 1. Carcass characteristics and longissimus proximate composition for Angus and Wagyu steers fed corn or hay-based diets for 8, 12, 16, or 20 mo

	Months on feed/diet									*P*-values		
	8 mo/corn		12 mo/hay		16 mo/corn		20 mo/hay					
Item	Angus	Wagyu	Angus	Wagyu	Angus	Wagyu	Angus	Wagyu	SE	Breed	Time	B x T[x]
Carcass weight, kg	323.4	252.3	307.7	283.0	407.8	357.2	403.	353.1	37.6	0.01	0.01	0.70
Skeletal maturity[a]	133.3[z]	140.0[z]	165.0[yz]	140.0[z]	167.5[yz]	172.5[y]	185.0[y]	185.0[y]	11.3	0.42	0.01	0.03
Lean maturity[a]	160.0	147.5	160.0	150.0	170.0	160.0	170.0	177.5	12.4	0.17	0.01	0.37
Overall maturity[a]	146.6	142.5	162.5	146.2	168.7	165.0	178.7	181.2	8.3	0.08	0.01	0.18
Marbling[b]	673.3	612.5	580.0	572.5	802.5	897.5	672.5	762.5	135.3	0.55	0.01	0.62
Quality grade[c]	483.3	462.5	443.7	468.7	531.2	562.5	487.3	518.7	44.4	0.30	0.01	0.63
No. steers grading USDA Prime, %	2/3	0/4	0/4	1/4	3/4	4/4	1/4	3/4				
Adjusted fat thickness, cm	1.44	0.95	1.30	1.05	2.51	1.53	1.90	1.30	0.45	0.01	0.01	0.44
Ribeye area, cm^2	78.3	68.4	71.8	68.9	76.0	87.3	85.2	82.6	8.8	0.75	0.01	0.15
KPH, %	3.00	2.88	2.63	3.13	2.75	3.00	2.50	3.25	0.51	0.07	0.99	0.42
Yield grade	3.33[c]	2.75[c]	3.33[c]	3.08[c]	5.17[a]	3.27[c]	4.04[b]	3.29[c]	0.56	0.01	0.01	0.03
Lipid, %	9.3[z]	6.1[z]	8.3[z]	7.8[z]	14.7[yz]	14.1[yz]	12.0[z]	20.4[y]	3.84	0.47	0.01	0.03
Moisture, %	67.7[y]	70.6[y]	68.7[y]	68.1[y]	62.9[yz]	62.1[yz]	67.2[y]	59.6[z]	3.35	0.24	0.01	0.04
Initial body weight, kg	208.7	169.1	207.5	175.1	218.6	174.3	205.5	175.3	6.9	0.01	0.98	0.98
Final body weight, kg	525.0	427.9	528.4	479.4	662.8	573.3	663.1	603.4	16.8	0.01	0.01	0.82
Cumulative ADG, kg	1.29	1.05	0.89	0.83	0.90	0.81	0.75	0.70	0.56	0.06	0.01	0.26

[a]A = 100; B = 200; C = 300; D = 400; E = 500.

[b]Practically Devoid = 100; Traces = 200; Slight = 300; Small = 400; Modest = 500; Moderate = 600; Slightly Abundant = 700; Moderately Abundant = 800; Abundant = 900.

[c]Standard = 200; Select = 300; Choice = 400; Prime = 500.

[x] Breed x diet interaction. Interaction means with different [yz]superscripts differ.

Table 2. Percentage of total fatty acids in subcutaneous adipose tissue of Wagyu and Angus steers fed U.S. and Japanese endpoints.

	Months on feed/diet												
	U.S. endpoint				Japanese endpoint								
	8 mo/Corn		12 mo/Hay		16 mo/Corn		20 mo/Hay			P-values			
Item	Angus	Wagyu	Angus	Wagyu	Angus	Wagyu	Angus	Wagyu	SE	Breed	Diet	End point	DxE[b]
16:0	27.6	26.1	28.5	26.3	25.9	25.7	26.8	24.4	1.69	0.01	0.79	0.03	0.54
16:1n-7	2.95	4.02	2.31	2.44	6.54	6.55	5.87	4.98	1.39	0.88	0.04	0.01	0.99
18:0	16.2	14.2	20.4	19.3	7.25	4.17	9.11	8.32	4.50	0.55	0.07	0.01	0.35
18:1n-9	37.5	39.3	32.1	35.4	41.7	42.8	39.9	44.4	3.10	0.03	0.04	0.01	0.05
18:2n-6	2.58	2.49	1.56	2.07	2.41	2.71	1.72	1.90	0.30	0.05	0.01	0.91	0.92
18:3n-3	0.00	0.09	0.23	0.30	0.05	0.19	0.14	0.18	0.11	0.05	0.01	0.71	0.03
SFA	47.9	43.7	52.8	48.8	36.9	36.8	40.3	35.9	4.91	0.09	0.09	0.01	0.29
MUFA	43.6	46.2	37.7	40.3	51.5	52.7	49.2	52.3	4.12	0.12	0.02	0.01	0.14
PUFA	2.91	3.24	2.29	3.00	3.27	3.46	2.58	3.09	0.46	0.01	0.01	0.16	0.77
MUFA:SFA	0.91	1.10	0.72	0.87	1.42	1.44	1.22	1.47	0.22	0.07	0.07	0.01	0.43
Index[y]	0.84	1.04	0.65	0.80	1.39	1.39	1.17	1.41	0.22	0.08	0.06	0.01	0.46
SCD activity[a]	4.92	6.32	8.57	7.91	13.3	10.4	9.88	12.0	2.69	1.00	0.40	0.01	0.08
SCD gene expression[c]	0.15	0.06	0.54	0.26	0.17	0.62	0.29	0.50	0.20	0.34	0.06	0.07	0.05

[a] nmol palmitoyl-CoA converted to palmitoleoyl-CoA per 7 min of incubation per mg protein.

[b] Diet x endpoint interaction. There wa a significant breed x endpoint interaction for SCD gene expression ($P = 0.01$).

[c] SCD/28S RNA ratio.

[y] Desaturation index = (14:1 + 16:1 + 18:1*cis*-9 +18:2*cis*-9,*trans*-11)/(14:0 + 16:0 + 17:0 + 18:0 + 18:1*trans*-11).