Genetic Correlations of Fatty Acid Concentrations with Carcass Traits in Angus-Sired Beef Cattle

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Summary and Implications

Fatty acid composition of beef is heritable in grain-fed calves. To select for beef that is more healthful, it is important to know the genetic correlations of specific fatty acid concentrations with carcass traits that have been under selection for several years. The most relevant fatty acids in beef for selection would be myristic acid, because of its impact on healthfulness, and oleic acid, because of its amount in beef.

Myristic acid has favorable genetic correlations with hot carcass weight, 12-13th rib subcutaneous fat thickness, and Warner-Bratzler shear force (-0.23, 0.27, and 0.31, respectively). Additionally, the genetic correlation of oleic acid with marbling is very strong and favorable (0.83). Unfortunately, myristic acid has a moderate antagonistic genetic correlation to marbling (0.31). In addition, oleic acid has weak to moderate antagonistic genetic correlations with hot carcass weight, 12-13th rib subcutaneous fat thickness, percentage kidney, pelvic, and heart fat, and Warner-Bratzler shear force (-0.14, 0.18, 0.36, and 0.12, respectively).

Information about the genetic correlations of traditional carcass traits and fatty acid concentrations will enable us to create a selection scheme that will create more healthful beef that meets the other carcass characteristics desired by the consumer.

Introduction

Beef demand is influenced by the perceived healthfulness of the product. Beef generally has been classified as high in saturated fatty acids, and this has driven some consumers away. Our group has reported previously that the percentage of fatty acids within the lipid does show evidence of being under genetic control. When developing a breeding program, it is important to know not only the heritability of a trait, but also the genetic relationships between traits to be included in the breeding goal. The objective of this study is to estimate genetic correlations between carcass traits and several fatty acids and fatty acid ratios that would be of interest for selection to make beef more healthful for consumers.

Materials and Methods

Cattle from the Iowa State University beef breeding project and the Iowa Beef Center's beef tenderness project were used for this study. There were 915 Angus-sired bulls and steers born in 2000, 2001, 2002, and 2003 and managed under a grain-fed calf feeding system utilized for this study. This data set represents 87 sires with one to 41 progeny.

Hot carcass weight was collected on the day of harvest. Carcass data traits of 12-13th rib subcutaneous fat thickness, 12-13th rib ribeye area, percentage kidney, pelvic, and heart fat, and marbling score were collected 24 to 48 hours after harvest. A sample of the *Longissimus dorsi* without external connective tissue was collected for fatty acid composition evaluation by gas chromatography. Beef tenderness was evaluated on a one inch thick steak that was aged for 14 days at 32º F before freezing. The steak was thawed, cooked to an internal temperature of 160º F, and allowed to cool for approximately 4 hours at room temperature; then, six ½ inch core samples were sheared using a Warner-Bratzler shear force attachment on a Texture Analyzer machine. The six measures of peak force to shear the samples were then averaged for further analysis.

Fatty acid concentrations were expressed as g of fatty acid / 100 g of lipid. In addition, the atherogenic index (AI), a measure of healthfulness of lipid composition, was calculated as: $AI = \frac{(4*14:0)+16:0}{\sum(MUFAs)+\sum(PUFAs)}$, where MUFAs are monounsaturated fatty acids and PUFAs are polyunsaturated fatty acids.

Three fatty acid desaturase ratios were calculated. The ratio of 16:1 to 16:0 (16:1/16:0) and of 18:1 to 18:0 (18:1/18:0) was calculated. The combination desaturase ratio of X:1 to X:0 (X:1/X:0) was calculated as:

$$(X:1/X:0) = \frac{16:1+18:1}{16:0+18:0}$$

Two fatty acid chain elongation ratios were calculated. The ratio of 16:0 to 14:0 (16/14) and of 18:0 to 16:0 (18/16) was calculated.

Genetic analyses were conducted with multiple two trait analyses by using the sire model option of MTDFREML. Management contemporary group was the only fixed effect included in these genetic analysis models. For this study, management contemporary group was defined from herd of origin, gender, feedlot dietary treatment, and harvest date. The MTDFREML program was run until first convergence of the model where the variance of the simplex was less than 10^{-10}. Reported heritability estimates are the average of the heritability estimates for each trait from the multiple analyses including that trait.

Results and Discussion

Means, standard deviations, and heritability estimates for the carcass traits and various fatty acids are reported in Table 1. Fatty acids with the largest concentrations in these beef samples were 16:0, 18:0, and 18:1. Fatty acids of interest for human health and showing the largest heritability estimates in beef were 14:0, 16:0, 16:1, 18:0, and 18:1. These five fatty acids all show heritability estimates of 0.20 to 0.49, which indicates that, much like carcass traits, fatty acids should respond to selection.

Myristic acid (14:0) is the most detrimental fatty acid for human health as indicated by the 4 × weighting in the atherogenic index. Fortunately, myristic acid has favorable genetic correlations to hot carcass weight, 12-13th rib subcutaneous fat thickness, and Warner-Bratzler shear force (-0.23, 0.27, and 0.31, respectively). Myristic acid has relatively low ($\leq \pm 0.10$) genetic correlation to 12-13th rib ribeye area and percentage kidney, pelvic, and heart fat. Unfortunately, myristic acid has a moderate antagonistic genetic correlation to marbling (0.31).

While the AI shows a considerable amount of genetic control ($h^2 = 0.52$), selection would need to be made for targeted increase of more healthful (monounsaturated and polyunsaturated) and decrease of unhealthful (saturated) fatty acids. Because AI is a ratio, there could be different values of healthful and unhealthful fatty acids that give a similar AI ratio. If selection was placed on the AI, that selection may not result in a directed change of fatty acid healthfulness. A more effective approach would be to develop a selection index to appropriately weight the desired changes in fatty acids to use for selection. Therefore, while the genetic correlations between AI and carcass traits may be interesting, they would not likely be utilized in a selection program.

Desaturase and elongation activity both show evidence of genetic control with heritability estimates of 0.25 to 0.40. Again, these ratios would not be selected upon directly; so, it is important to investigate genetic correlations of specific MUFAs and PUFAs with carcass traits. Oleic acid (18:1) is the fatty acid in the highest concentration in beef and would make sense to pursue increasing through a breeding program. The genetic correlation of oleic acid with marbling is very strong and favorable (0.83). Unfortunately, most of the other carcass traits have weak to moderate antagonistic genetic relationship with oleic acid such as hot carcass weight ($r_g = -0.14$), 12-13th rib subcutaneous fat thickness ($r_g = 0.18$), percentage kidney, pelvic, and heart fat ($r_g = 0.36$), and Warner-Bratzler shear force ($r_g = 0.12$). More work will be necessary to determine the appropriate selection index weightings to be applied to carcass traits and specific fatty acids in order to create beef which is more desirable to consumers from a healthfulness, flavor, tenderness, and cost perspective.

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Table 1. Means, standard deviations, and heritability estimates for carcass traits and several fatty acids.

Trait	Mean	S. D.[a]	h^2
Hot Carcass Weight, lb	728.7	62.2	0.15
12-13th Rib Subcutaneous Fat Thickness, in	0.40	0.13	0.51
12-13th Rib Ribeye Area, in^2	12.22	1.12	0.28
Percentage Kidney, Pelvic, and Heart Fat, %	2.13	0.34	0.24
Marbling Score[b]	5.43	1.00	0.35
Warner-Bratzler Shear Force, lb	6.56	3.48	0.27
Lipid, %	4.55	1.77	0.14
Fatty Acid Concentration[c]			
14:0, %	2.81	0.49	0.50
14:1(n5), %	0.68	0.28	0.14
16:0, %	26.48	1.94	0.43
16:1(n7), %	3.48	0.67	0.48
18:0, %	12.74	1.44	0.20
18:1(n7,n9), %	41.34	3.26	0.38
18:2(n6), %	7.02	2.99	0.24
AI[d]	0.67	0.08	0.52
Desaturase Ratios			
16:1/16:0[e]	0.13	0.02	0.40
18:1/18:0[f]	3.29	0.50	0.25
X:1/X:0[g]	1.15	0.11	0.40
Elongation Ratios			
16/14[h]	9.64	1.55	0.32
18/16[i]	0.49	0.08	0.28

[a] S. D. = standard deviation.
[b] 3.00 = Traces[00]; 4.00 = Slight[00]; 5.00 = Small[00]; 6.00 = Modest[00]; 7.00 = Moderate[00]; 8.00 = Slightly Abundant[00]; 9.00 = Moderately Abundant[00]
[c] Fatty acid concentrations are expressed as g of fatty acid / 100 g of lipid, (%)
[d] AI = atherogenic index
[e] 16:1/16:0 = concentration 16:1 / concentration 16:0
[f] 18:1/18:0 = concentration 18:1 / concentration 18:0
[g] X:1/X:0 = concentration (16:1+18:1) / concentration (16:0+18:0)
[h] 16/14 = concentration 16:0 / concentration 14:0
[i] 18/16 = concentration 18:0 / concentration 16:0

Table 2. Genetic correlations between carcass traits and several fatty acids.

Trait	HCW	12FT	12REA	KPH	MARB	WBS
Hot Carcass Weight (HCW)	...	...	...	...	...	...
12-13th Rib Subcutaneous Fat Thickness (12FT)	0.03	...	...	...	...	...
12-13th Rib Ribeye Area (12REA)	0.52	-0.17	...	...	...	...
Percentage Kidney, Pelvic, and Heart Fat (KPH)	0.85	0.35	0.69	...	...	...
Marbling Score[a] (MARB)	-0.19	0.29	-0.06	0.32	...	...
Warner-Bratzler Shear Force (WBS)	0.47	0.24	0.13	0.51	0.06	...
Lipid	-0.44	0.30	-0.44	0.00	1.00	0.11
Fatty Acid Concentration[b]						
14:0	-0.23	0.27	-0.10	0.03	0.32	0.31
14:1(n5)	-0.42	0.14	-0.07	-0.32	0.24	0.29
16:0	-0.24	0.17	-0.25	-0.28	0.26	-0.04
16:1(n7)	0.06	0.16	0.17	0.07	0.51	-0.14
18:0	0.00	-0.54	-0.50	-0.28	-0.45	-0.07
18:1(n7,n9)	-0.14	0.18	0.01	0.36	0.83	0.12
18:2(n6)	0.43	-0.17	0.24	-0.03	-0.93	-0.04
AI[c]	-0.23	0.17	-0.23	-0.16	0.25	0.11
Desaturase ratios						
16:1/16:0[d]	0.13	0.13	0.32	0.21	0.57	-0.15
18:1/18:0[e]	-0.13	0.49	0.30	0.36	0.89	0.11
X:1/X:0[f]	0.04	0.21	0.26	0.51	0.68	0.14
Elongation ratios						
16/14[g]	0.18	-0.38	0.00	-0.19	-0.39	-0.46
18/16[h]	0.21	-0.45	-0.09	0.02	-0.46	-0.07

[a] 3.00 = Traces[00]; 4.00 = Slight[00]; 5.00 = Small[00]; 6.00 = Modest[00]; 7.00 = Moderate[00]; 8.00 = Slightly Abundant[00]; 9.00 = Moderately Abundant[00]

[b] Fatty acid concentrations are expressed as g of fatty acid / 100 g of lipid, (%)

[c] AI = atherogenic index.

[d] 16:1/16:0 = concentration 16:1 / concentration 16:0

[e] 18:1/18:0 = concentration 18:1 / concentration 18:0

[f] X:1/X:0 = concentration (16:1+18:1) / concentration (16:0+18:0)

[g] 16/14 = concentration 16:0 / concentration 14:0

[h] 18/16 = concentration 18:0 / concentration 16:0