FATTY ACID PROFILES OF NORTH AMERICAN BEEF PRODUCED USING ORGANIC AND NATURAL SYSTEMS

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Abstract – Organic and natural beef are gaining popularity in Canada; however, their nutritional profiles have not been evaluated at retail. Fatty acid (FA) profiles of beef from conventional (Conv), organic and natural grain (O-Grain, N-Grain), and organic and natural grass-based (O-Grass, N-Grass) production systems were compared. Total fat in Conv and N-Grain beef was greater than other systems (*P*<0.001). This did not affect proportions of saturated FA, but proportions of polyunsaturated FA (PUFA) were greater and *cis*-monounsaturated FA (*c*-MUFA) reduced in O-Grass and N-Grass compared to Conv and N-Grain beef (*P*<0.05). Omega-3 (n-3) FA were over three times greater for O-Grain, O-Grass, and N-Grass beef than Conv and N-Grain beef (*P*<0.001), whereas omega-6 (n-6) were similar, resulting in n-6/n-3 ratios <4:1 vs. ~9:1. Proportions of PUFA biohydrogenation products with potential health benefits (i.e. *trans*-11-18:1 and *cis*-9,*trans*-11 conjugated linoleic acid) were greatest in O-Grass and lowest in Conv beef (*P*<0.05). Overall, the healthfulness of FA profiles of O-Grass and N-Grass beef was judged to be superior to Conv and N-Grain beef. O-Grain beef, however, is also worthy of consideration given its intermediate FA profile and potential for improved animal performance and overall meat quality.

I. INTRODUCTION

Grain-based diets, typical of those used in conventional Canadian beef production, yield well-marbled meat. However, such diets also result in less healthful fatty acid (FA) profiles, including low polyunsaturated FA (PUFA) content and high omega-6/omega-3 (n-6/n-3) ratios (1). A recent survey of Canadian retail beef (1) also noted diets high in barley grain enhance *t*10-18:1 content, a biohydrogenation intermediate (BI) with potential atherogenic effects (2). Consumers are increasingly aware of the link between diet and health, and are increasingly more conscientious of fat and fatty acid intake. Health recommendations call for reduced overall fat and higher n-3 PUFA intake. Lean beef can contribute positively as red meat represents an alternative source of daily n-3 long-chain (LC, ≥20carbon) PUFA intake in many cultures (3).

Canadian beef producers are responding to demands for healthier, more wholesome beef as evidenced by an increased prevalence of niche market organic and natural grain- and grass-fed beef available at retail. Organic products are well recognized by consumers, but their price can be a deterrent and consumer focus is often on pharmaceutical inputs such as growth promotants and antibiotics. Strict guidelines govern organic beef production, including the use of organic feeds, which ultimately poses a challenge in sourcing affordable feed supplies and contributes to the premium demanded for organic products. "Natural" is a relatively newer label claim, in principle reflecting adherence to similar guidelines as organic production regarding growth promotant and antibiotic use, but non-organic feeds can be used, which tends to have appeal to the average consumer. There is very little data reported on fatty acid profiles of niche market retail beef in Canada, and the objectives of the present study were to source and analyze fatty acid profiles in lean meat collected from ribeye steaks produced using conventional, organic and natural grain-fed, and organic and natural grass-fed production systems.

II. MATERIALS AND METHODS

Retail samples

Ribeye steaks were purchased from multiple grocery stores throughout Western Canada offering conventional as well as niche market organic and natural grain- and grass-fed beef. Multiple steaks (3 to 4) sold under different retail labels representing different individual farms were purchased at each store and grouped according to production practice. Beef from Canadian conventional (Conv, n = 23, retail $26/kg) production systems are typically fed diets exceeding 85% barley during the finishing period. Certified organic beef systems require the use of certified feeds, consisting of 100% forage for organic grass (O-Grass, n = 22, retail $45/kg), whereas organic grain (O-Grain, n = 24, retail $52/kg) can include up to 40% grain (4). Feeding regulations for natural grass (N-Grass, n = 24, retail $38/kg) and natural grain (N-Grain, n = 23, retail $38/kg) are not defined; however, they are assumed to be similar to organic guidelines.

Fatty acid analysis

Visible fat was dissected from ribeye steaks, and total lipids were extracted from lean muscle by a modified Folch procedure (1) and methylated using base (sodium methoxide) and then acid (methanolic HCl) catalysts. Fatty acid methyl esters (FAME) were analyzed by gas chromatography using a 100 m column and a temperature program with a 175 ºC plateau as described by Kramer *et al*. (5). A separate analysis was conducted for separation of major conjugated linoleic acid (CLA) isomers (*t*7,*c*9-CLA and *c*9,*t*11-CLA), using a 30 m SLB-111 highly polar column (6). Peaks were identified by comparison to commercial reference standards (Nu-Chek Prep, Inc., MN, USA) and published elution orders (5).

Statistical analysis

The data was analyzed as a one-way ANOVA using the PROC MIXED procedure of SAS v9.2 (Statistical Analysis System, NC, USA). The retail farm label was used as a random factor. Means and standard error are reported and differences judged as significant when $P<0.05$.

III. RESULTS AND DISSCUSSION

Total fat content (mg/g of muscle) was greater for Conv and N-Grain beef compared to O-Grain, N-Grass, and O-Grass ($P<0.001$, Table 1). Proportion of polyunsaturated fatty acids (PUFA) were greater for O-Grass and N-Grass compared to Conv or N-Grain beef, whereas proportions in O-Grain beef were intermediate ($P<0.01$, Table 1). Production system did not affect the proportions of total n-6 or 18:2n-6, but higher proportions of 20:4n-6 were found in O-Grass and N-Grass compared to Conv or N-Grain beef, whereas proportions in O-Grain beef were again intermediate ($P<0.05$). Diet strongly affected proportions of 18:3n-3, with O-Grain, O-Grass, and N-Grass beef all having two- to three-fold greater concentrations compared to Conv or N-Grain beef ($P<0.001$, Fig. 1). Clearly, feeding high forage-to-concentrate ratio diets increased 18:3n-3 intake and in turn enhanced proportions of 18:3n-3 in beef. Diet effects on 18:3n-3 extended to its LC-PUFA derivatives, with 20:5n-3, 22:5n-3, and 22:6n-3 proportions enhanced by feeding forage ($P<0.01$, Fig. 1). The n-6/n-3 ratio was also superior (i.e. lower than the recommended ratio of 4:1) in O-Grain, O-Grass, and N-Grass beef, whereas the ratio was close to 9:1 for Conv and N-Grain beef ($P<0.001$). Close resemblance in PUFA profiles between N-Grain and Conv meat suggested a similarly high proportion of grain was fed to these cattle. Moderate grain feeding, as with O-Grain practices (i.e. >60% forage diet), likely enhanced the proportion of n-3 FA in meat, resulting in an n-6/n-3 ratio similar to O-Grass and N-Grass beef. Regular consumption of meat with a low n-6/n-3 ratio can enhance blood n-3 LC-PUFA, which may have important long-term health implications such as reducing the risk of developing cardiovascular disease (7). Given the low intake of marine n-3 PUFAs in many cultures, regular consumption of beef fed high forage-to-concentrate ratios would be a positive step towards increasing LC-PUFA intake to offset the high n-6/n-3 ratio typical of Western diets (3).

Trans-MUFAs (*t*-MUFA) accounted for the majority of BI in beef, but total *t*-MUFA proportions did not differ between production systems. Proportions of individual *t*-MUFA isomers were, however, different between systems, with *t*11-18:1 being greatest for O-Grass and lowest for Conv beef ($P<0.001$, Table 1). In contrast, grain feeding increased *t*10-18:1 proportions, being greatest for Conv and lowest for O- and N-Grass ($P<0.01$). In ruminant tissue, *t*11-18:1 is generally assumed to be the most prominent *t*-MUFA; however, diets with increased contents of rapidly fermentable starch shift biohydrogenation pathways, making *t*10-18:1 the predominant

BI. Our findings concur with the *t*11- to *t*10-18:1 shift recently documented in a survey of Canadian retail beef (1). This shift has important implications for the content of *c*9,*t*11-CLA, as most *c*9,*t*11-CLA is synthesized endogenously from *t*11-18:1 via stearoyl-CoA desaturase (SCD). As such, the proportion of *c*9,*t*11-CLA in O-Grain, O-Grass, and N-Grass meat was two to three times greater than Conv meat (*P*<0.001). Enhanced *t*11-18:1 and *c*9,*t*11-CLA content is considered desirable, owing to their purported health benefits in animal models (1-2).

The proportion of *cis*-monounsaturated FA (*c*-MUFA), consisting predominantly of *c*9-18:1, was greater in Conv and N-Grain meat compared to O-Grass and N-Grass meat, while O-Grain was intermediate (*P*<0.05, Table 1). Increased endogenous fat synthesis (i.e. marbling), typical of high energy grain-based diets, is correlated with the up-regulation of SCD expression and conversion of 18:0 to *c*9-18:1 (8). Alternatively, *c*-MUFA synthesis tends to be lower for forage-based diets due to a combination of greater 18:3n-3 intake and deposition inhibiting SCD expression as well as restricted endogenous fat synthesis associated with lower energy diets (8). The proportion of saturated FA (SFA), comprised mainly of 16:0 and 18:0 as a result of endogenous fat synthesis and extensive biohydrogenation of dietary PUFA, did not differ between production systems.

IV. CONCLUSION

Overall, beef produced using O-Grass and N-Grass production systems had nearly indistinguishable and superior FA profiles, having the greatest proportions of total PUFA, n-3 FA, healthy BI, and the lowest n-6/n-3 ratios. O-Grain produced beef is, however, also worthy of consideration given its intermediate fatty acid profile and potential advantages in terms of animal performance and overall meat quality. Present production practices suggest no health advantages of N-Grain vs. Conv meat, yet there is the potential to improve the FA profile by adopting feeding guidelines similar to O-Grain production practices.

Table 1 Fatty acid profile (% FAME) of ribeye muscle from beef reared under conventional feedlot feeding compared to niche market organic and natural grain, and organic and natural grass feeding systems.

	Conv	O-Grain	N-Grain	O-Grass	N-Grass	s.e.m.	*P* value
mg/g muscle	84.5^{a}	54.5^{b}	84.9^{a}	31.9^{b}	38.6^{b}	7.9	<0.001
PUFA	4.7^{b}	5.8^{ab}	4.2^{b}	7.0^{a}	7.0^{a}	0.60	<0.01
n-6	4.1	4.1	3.6	4.6	4.8	0.40	
18:2n-6	3.1	2.8	2.6	3.0	3.3	0.30	
20:4n-6	0.6^{b}	0.8^{ab}	0.6^{b}	1.0^{a}	1.1^{a}	0.12	<0.05
n-3	0.6^{c}	1.7^{b}	0.5^{c}	2.5^{a}	2.2^{ab}	0.23	<0.001
n-6/n-3	8.9^{a}	3.3^{b}	8.9^{a}	1.9^{b}	2.5^{b}	1.30	<0.001
t-MUFA	2.4	3.0	2.8	3.5	3.0	0.40	
*t*10-18:1	0.99^{a}	0.50^{bc}	0.77^{ab}	0.18^{c}	0.17^{c}	0.17	<0.01
*t*11-18:1	0.7^{d}	1.5^{bc}	1.0^{cd}	2.3^{a}	1.9^{ab}	0.22	<0.001
*c*9,*t*11-CLA	0.12^{d}	0.28^{b}	0.14^{cd}	0.38^{a}	0.23^{bc}	0.03	<0.001
c-MUFA	44.1^{a}	41.2^{ab}	43.5^{a}	39.2^{b}	39.0^{b}	1.30	<0.05
*c*9-18:1	36.3^{a}	34.7^{ab}	36.5^{a}	32.7^{b}	32.9^{b}	1.00	<0.05
SFA	46.8	47.3	47.6	47.1	47.7	0.80	
16:0	27.9	26.5	27.1	26.6	26.0	0.50	
18:0	14.0	16.3	15.8	16.0	17.2	0.80	

s.e.m.-standard error of the mean; significance (P<0.05) indicated by letter $^{a\text{-}d}$.

PUFA = n-6 + n-3; n-6 = 18:2n-6 + 18:3n-6 + 20:3n-6 + 20:4n-6; n-3 = 18:3n-3 + 20:3n-3 + 20:5n-3 + 22:5n-3 + 22:6n-3; *t*-MUFA = *t*9-18:1 + *t*10-18:1 + *t*11-18:1 + *t*12-18:1 + *t*13/*t*14-18:1 + *t*16-18:1; *c*-MUFA = *c*9-14:1 + *c*9-16:1 + *c*9-18:1 + *c*11-18:1 + *c*13-18:1 + *c*9-20:1; SFA = 14:0 + 16:0 + 18:0 + 20:0.

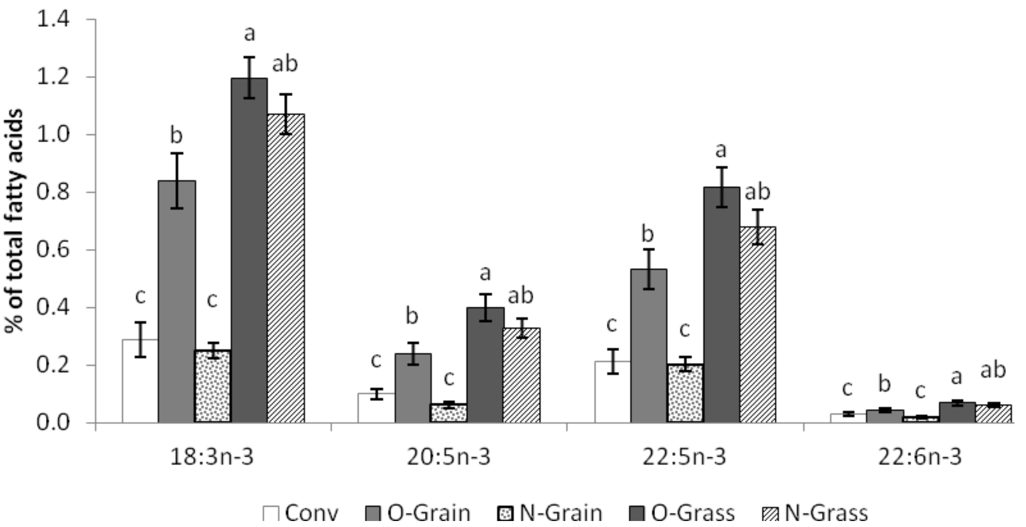

Fig. 1. Proportions of n-3 fatty acids (% total FAME) from beef fed under conventional feedlot, organic grain, natural grain, organic grass, or natural grass production systems. Means (± s.e.m.) with significance ($P<0.05$) within a particular fatty acid are indicated by letters [(a-c)].

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