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Effects of feeding flaxseed or sunflower-seed in high-forage diets on beef production, quality and fatty acid composition

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ABSTRACT

Yearling steers were fed 70:30 forage:concentrate diets for 205 d, with either grass hay (GH) or red clover silage (RC) as the forage source, and concentrates containing either sunflower-seed (SS) or flaxseed (FS), each providing 5.4% oil to diets. Feeding diets containing SS versus FS significantly improved growth and carcass attributes ($P < 0.05$), significantly reduced meat off-flavor intensity ($P < 0.05$), and significantly increased intramuscular proportions of vaccenic (*t*11-18:1), rumenic (*c*9,*t*11-CLA) and $n-6$ fatty acids (FA, $P < 0.05$). Feeding diets containing FS versus SS produced significantly darker and redder meat with greater proportions of atypical dienes ($P < 0.05$). A significant forage × oilseed type interaction ($P < 0.05$) was found for $n-3$ FA, α-linolenic acid, and conjugated linolenic acid, with their greatest intramuscular proportions found when feeding the RC-FS diet. Feeding GH versus RC also significantly improved growth and carcass attributes, sensory tenderness ($P < 0.05$) and significantly influenced intramuscular FA composition ($P < 0.05$), but overall, forage effects on FA profiles were limited compared to effects of oilseed.

1. Introduction

Beef lipids typically have high contents of saturated fatty acids (SFA), compared to tissues from monogastric species, due to extensive ruminal biohydrogenation (BH) of polyunsaturated fatty acids (PUFA; Raes, De Smet, & Demeyer, 2004). Efforts have been made to increase amounts of PUFA in beef, particularly omega-3 ($n-3$) PUFA and PUFA BH intermediates, which may have health benefits for consumers (Dilzer & Park, 2012; Molendi-Coste, Legry, & Leclercq, 2011). The challenges have been to define appropriate diets and rumen conditions to promote accumulation of PUFA and their BH intermediates in beef.

To substantially increase PUFA and their BH intermediates in beef, typically an oil or oilseed source of PUFA must be fed while creating rumen conditions conducive to promote PUFA bypass or partial as opposed to complete BH (Jenkins & Bridges, 2007). To this end, our research group has undertaken a series of studies feeding diets containing 10–15% flaxseed (FS), a rich source of α-linolenic acid (18:3$n-3$, ALA) to cattle and resulting in increased deposition of $n-3$ PUFA in total muscle FA by 0.7–1.1% (Juárez et al., 2011; Mapiye et al., 2013; Nassu et al., 2011). The type (He et al., 2012; Nassu et al., 2011) and level (Aharoni, Orlov, & Brosh, 2004; Mir et al., 2003) of forage can, however, have overriding effects on accumulation of PUFA BH intermediates in beef. Juárez et al. (2011) fed steers 10% FS in a high (73%) barley grain diet with 22% alfalfa/brome hay, and found limited accumulations of either ALA or its BH intermediates. In this study, the PUFA BH pathway favored accumulation of *trans* (*t*)13/*t*14-18:1 instead of *t*11-18:1 (vaccenic acid, VA), and atypical dienes (AD, i.e., non-conjugated, non-methylene interrupted dienes) instead of conjugated linoleic acid (CLA). Nassu et al. (2011) fed FS to cull cows in 50:50 forage:concentrate diets with either grass hay (GH) or barley silage as the forage source for an extended period (20 weeks), and found that feeding GH-FS promoted greater accumulations of PUFA BH intermediates, with VA as the major *trans* mononene. In addition, feeding GH-FS yielded more AD than barley silage-FS, and for both diets, AD exceeded amounts of total CLA and total $n-3$ PUFA.

Abbreviations: AD, atypical dienes; ADG, average daily gain; ALA, α-linolenic acid; BCFA, branched-chain fatty acids; BH, biohydrogenation; *c*, *cis*; CLA, conjugated linoleic acids; CLNA, conjugated linolenic acids; d, days; DHA, docosahexaenoic acid; DM, dry matter; DMI, dry matter intake; DPA, docosapentaenoic acid; EPA, eicosapentaenoic acid; FA, fatty acids; FAME, fatty acid methyl esters; GC, gas chromatography; FS, flaxseed; GH, grass hay; LA, linoleic acid; LT, *longissimus thoracis*; MUFA, monounsaturated fatty acids; $n-3$, omega-3; $n-6$, omega-6; PPO, polyphenol oxidase; PUFA, polyunsaturated fatty acids; RC, red clover silage; RA, rumenic acid; SS, sunflower seed; SFA, saturated fatty acids; *t*, *trans*; VA, vaccenic acid; vs., versus.

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Recently, Mapiye et al. (2013) found feeding 15% FS in a 70% forage (red clover silage, RC) diet for 215 d provided even greater accumulations of PUFA BH intermediates in beef lipids with *t*11-18:1 reaching a high of 9.5% in perirenal fat, *cis* (*c*)9,*t*11-18:2 (rumenic acid, RA) reaching a high of 2.9% in subcutaneous fat, and *t*11,*c*15-18:2 reaching a high of 1.9% in perirenal fat. The increased amounts of PUFA BH intermediates were in part attributed to the amount and duration of FS feeding. In addition, the relatively high level of polyphenol oxidase (PPO) activity in RC may have played a role, as PPO reduces rates of PUFA lipolysis and BH in the rumen (Van Ranst, Lee, & Fievez, 2011) thereby enhancing deposition of PUFA and their BH intermediates in tissues (Lee, Evans, Nute, Richardson, & Scollan, 2009). The benefits of feeding RC were, however, not evaluated in comparison with other forage sources such as GH which have demonstrated positive effects on the accumulation of PUFA BH intermediates in beef (Nassu et al., 2011).

Feeding sources of linoleic acid (18:2*n*−6, LA), for example sunflower-seed (SS) or oil, in high-forage diets can also increase PUFA BH intermediates in beef, but these are mostly restricted to VA and RA (Basarab, Mir, et al., 2007; Noci, French, Monahan, & Moloney, 2007). Feeding SS or FS in high forage diets can, therefore, increase VA and RA in beef, and feeding FS can also increase other ALA specific BH intermediates. Consuming VA and RA may have positive health effects for humans (Dilzer & Park, 2012; Jaudszus et al., 2012; Sofi et al., 2010), but effects of many other PUFA BH intermediates have not been evaluated. Consequently, the objectives of the present experiment were to feed steers a high forage diet (either RC or GH) in combination with oilseeds (either FS or SS) for an extended period, and determine which diets would lead to the greatest accumulations of PUFA and their related BH intermediates in beef. In addition, animal performance, carcass traits, meat quality and sensory attributes were evaluated since increasing the degree of FA unsaturation in beef accentuates oxidation of fat, possibly leading to unacceptable changes in shelf-life and eating quality (Wood et al., 2004).

2. Materials and methods

2.1. Animals and diets

Sixty-four 12-month-old British × Continental crossbred steers with an initial mean body weight of 423.2 ± 5.93 kg were used in the current study conducted at Lacombe Research Centre, Alberta, Canada. Animal care was in compliance with the principles and guidelines established by the Canadian Council on Animal Care (CCAC, 1993). Steers were stratified by weight to four experimental diets, with two pens of eight steers per diet. The four diets were GH-FS, GH-SS, RC-FS and RC-SS. On a dry matter (DM) basis, diets contained 70% forage and either SS (18.4%) or FS (14.3%), with oilseeds added to provide the same amount of oil (5.4%, DM basis; Table 1) to each diet. All diets included 4.2% of a vitamin mineral supplement (Table 1) and in an attempt to equalize the digestible energy of the diets, additional ground barley grain was added to the diets containing SS, and additional barley straw was added to the diets containing FS. Flaxseed was triple rolled, while SS was fed whole. Steers in each pen were group fed to appetite and were all capable of feeding at the feed bunk at the same time (0.8 m of space at the bunk per animal). Steers had free access to fresh, clean water. Feed was provided once daily (feed DM equaling ~2.5% body weight) and the amount adjusted so that 10–15% orts were present after 18 h with all feed being consumed by 24 h. During the study period one animal from the GH-FS treatment was withdrawn due to lameness unrelated to dietary treatment.

2.2. Feed analysis

Feed samples were collected weekly and stored at −40 °C, then pooled monthly before determination of DM, minerals, crude fat, crude protein (AOAC, 2006), neutral detergent fiber and acid detergent fiber (Van Soest, Robertson, & Lewis, 1991). Fatty acids from the finishing total mixed ration were extracted and methylated as described by Sukhija and Palmquist (1988) and analyzed according to Dugan et al. (2007).

Table 1
Nutrient and fatty acid composition of the experimental diets.

Variable	Diet[a]			
	GH-FS	GH-SS	RC-FS	RC-SS
Diet ingredients (% DM basis)				
Red clover silage	0.0	0.0	70.0	70.0
Grass hay	70.0	70.0	0.0	0.0
Barley straw	11.5	0.0	11.5	0.0
Sunflower-seed	0.0	18.4	0.0	18.4
Flaxseed	14.3	0.0	14.3	0.0
Vitamin/mineral supplement[b]	4.2	4.2	4.2	4.2
Barley grain	0.0	7.4	0.0	7.4
Nutrient composition (DM basis)				
Dry matter (%)	93.1	93.0	46.9	46.9
Crude protein (%)	13.3	13.4	14.2	14.0
Crude fat (%)	6.4	6.6	8.2	8.4
Calcium (%)	1.1	1.1	1.1	1.2
Phosphorus (%)	0.3	0.3	0.3	0.2
ADF (%)	44.3	45.4	43.0	44.0
NDF (%)	53.2	57.6	55.5	61.6
Digestible energy[c] (Mcal/kg)	2.08	2.02	2.16	2.10
Fatty acid (% of total fatty acids)				
14:0	0.2	0.2	0.1	0.1
16:0	8.6	10.2	7.5	8.4
18:0	3.0	4.1	2.9	4.2
20:0	0.4	0.5	0.3	0.4
22:0	0.7	0.9	0.4	0.8
24:0	0.6	0.5	0.4	0.4
*c*9-18:1	11.6	11.3	11.6	11.7
*c*11-18:1	0.8	0.9	0.8	0.7
18:2*n*−6	23.4	66.0	21.4	70.4
18:3*n*−3	50.7	5.3	54.6	2.8

[a] GH-FS, grass hay + flaxseed; GH-SS, grass hay + sunflower-seed, RC-FS, red clover silage + flaxseed; RC-SS, red clover silage + sunflower-seed.
[b] Vitamin/mineral supplement per kg DM contained 1.86% calcium, 0.93% phosphorous, 0.56% potassium, 0.21% sulfur, 0.33% magnesium 0.92% sodium, 265 ppm iron, 314 ppm manganese, 156 ppm copper, 517 ppm zinc, 10.05 ppm iodine, 5.04 ppm cobalt, 2.98 ppm selenium, 49,722 IU/kg vitamin A, 9944 IU/kg vitamin D3, and 3222 IU/kg vitamin E.
[c] Digestible energy was calculated according to Bull (1981).

2.3. Growth measurements and slaughter procedure

Individual steer weights were measured monthly and average daily gain (ADG) was calculated by dividing each animal's body weight by days on-test. Animal growth and DM intake (DMI) were recorded from the start of the experiment until the first group of animals were slaughtered due to difficulties in measuring DMI when numbers of animals per pen were reduced. Backfat thickness was measured monthly by a certified ultrasound technician using an Aloka 500 V diagnostic real-time ultrasound with a 17 cm 3.5 MHz linear array transducer (Overseas Monitor Corporation Ltd., Richmond, B.C., Canada) following procedures of Brethour (1992). Steers were slaughtered at the Lacombe Research Centre abattoir over four slaughter dates in November 2011 (two steers/pen/diet/slaughter day) at an average of 205 d on feed corresponding to subcutaneous fat depths of 5–8 mm between the 12th and 13th rib over the right *longissimus thoracis* (LT) muscle of each animal.

On mornings of slaughter, animals were transported 2 km to the Lacombe Research Centre abbatoir. At slaughter, final live weights were recorded and steers were stunned, exsanguinated and dressed in a commercial manner. Following carcass splitting, trimmed side weights were recorded and initial (45 min) pH and temperature were recorded caudal to the grade site on the left LT using a Hanna HI99163 pH meter equipped with a Hanna Smart electrode FC232 for meat (Hanna Instruments, Laval QC, Canada). Upon entry into the cooler, stainless steel thermocouples (10 cm) were placed into the right LT ~2.5 cm anterior to the