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Fatty acid composition of adipose tissue and muscle from Jersey steers was affected by finishing diet and tissue location

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ABSTRACT

To determine the impacts of finishing diet and tissue type and location on fatty acid composition and palatability of Jersey beef, twenty steers were assigned to a factorial treatment design with initial weight (Light vs. Heavy) and finishing diet (70 vs. 85% concentrate) as treatments. Ribeye steaks were collected for sensory evaluation. Muscle, seam and subcutaneous (s.c.) fat from steaks, kidney fat (KF) and omental fat (OMF) were collected for fatty acid analysis. Initial weight and finishing diet had little impact on beef palatability. The 85% concentrate decreased polyunsaturated fatty acids (PUFA) in muscle and increased *trans* fatty acids in all tissues ($P<0.05$). The monounsaturated:saturated fatty acid ratio (MUFA:SFA) was highest in s.c. fat, intermediate in muscle and seam fat, and lowest in KF and OMF. The PUFA:SFA was highest in muscle, intermediate in s.c. and seam fat, and lowest in KF and OMF. Fatty acid composition differed greatly among tissues and the lower concentrate diet increased omega-3 and PUFA percentages in muscle.

1. Introduction

Jersey steer calves have little or no value to most dairy and beef operations currently. Beef cattle feeders are unwilling to purchase and raise these animals due to their slow growth rates and small carcass and retail product weights (Cole, Ramsey, & Hobbs, 1964; Marshall, 1994). However, Jersey cattle are known for their propensity to marble or deposit fat within muscles (Cole et al., 1964; Marshall, 1994). According to Siebert, Pitchford, Malau-Aduli, Deland, and Bottema (1999), early maturing breed (Jersey, Angus and Wagyu; 4.7–4.8%) sired cattle produced greater intramuscular fat than the later maturing crosses (Hereford, South Devon, Limousin and Belgian Blue; 3.2–4.2%). Also, Jersey beef tends to have a higher concentration of MUFAs than some other breeds (Siebert et al., 1999). This attribute is becoming appealing due to the discovery that compared to SFAs, MUFAs lowered blood low density lipoprotein cholesterol levels (Nydahl, Gustafsson, & Vessby, 1994; Williams et al., 1999). In addition, Jersey beef possessed eating quality equivalent or even superior to Hereford and Angus beef (Cole et al., 1964). Therefore, Jersey beef has its own marketing value and research aiming to improve production efficiency without sacrificing its valuable merits is necessary.

A recent study by Lehmkuhler and Ramos (2008) indicated that Jersey steers had a better ability to produce beef under a lower concentrate diet management compared with Holsteins. Overall ADG decreased for both breeds with lower concentrate levels in the diet, but ADG for the Holsteins decreased more than the Jerseys (6.5 vs. 3.4%). The impact of diet on fatty acid composition and palatability of Jersey beef was not studied, and therefore was examined in this study. In addition, fatty acid compositions of tissues from different anatomical locations were analyzed and compared. The results will help elucidate the fatty acid distribution in the body of Jersey steers and provide a foundation for future studies aiming to manipulate the distribution of fat or fatty acid composition in the body of cattle. We hypothesized that lowering the energy content in the diet would not significantly affect Jersey steer commercial value, especially marbling. However, fatty acid composition of muscle and adipose tissues might change with different energy levels in the finishing diet. In addition, the anatomical location of adipose tissues would have a significant influence on fatty acid composition. For instance, the saturation of fatty acids was expected to decrease from subcutaneous to body cavity fat depots.

2. Materials and methods

All procedures involving animals were approved by the Oregon State University Institute of Animal Care and Use Committee.

2.1. Animal management and sample collection

The weight of steers at the start of this project was not consistent, therefore initial weight was considered as a treatment factor.

Abbreviations: s.c., subcutaneous; KF, kidney fat; OMF, omental fat; PUFA, polyunsaturated fatty acid; TFA, *trans* fatty acid; MUFA, monounsaturated fatty acid; SFA, saturated fatty acid; ADG, average daily gain; DM, dry matter; SSF, slice shear force; HCW, hot carcass weight; REA, ribeye area; BF, back fat; CLA, conjugated linoleic acids.

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Twenty16-week old purebred Jersey steers were divided into two weight groups (Light, 77.4 ± 2.48 kg vs. Heavy, 96.7 ± 2.53 kg), with two pens per group. Steers were pen fed once per day (8:00 AM) with orts quantified the following day before feeding during the growing phase. Steers received the growing phase 1 (G1) diet until they reached an average weight of 184.5 ± 4.06 kg per head in the pen, then they were switched to the G2 diet. The steers were kept on growing phase diets for 169 days. As expected, the Heavy group had a greater DM intake than the Light group (5.0 vs. 4.3 ± 0.03 kg/d; $P<0.01$). However, the ADG and feed efficiency (feed: gain ratio) were similar between Heavy and Light groups (1.0 vs. 0.9 ± 0.03 kg/d and 5.2 vs. 4.8 ± 0.15; $P>0.05$).

By 40 weeks of age, steers reached an average weight of 244.2 ± 5.04 kg and were randomly assigned to one of the two finishing diets (70 vs. 85% concentrate; F70 vs. F85) within weight groups (n = 5). Each pen was setup with individual feeders (Calan Broadbent Feeding System, Northwood, NH) and steers were individually fed twice per day (8:00 AM and 4:00 PM) with leftover feed quantified the following day before the AM feeding. Growing and finishing phase diet composition and nutrient analysis are shown in Table 1.

During finishing phase, marbling at the 12th–13th rib interface was monitored by ultrasound (UMARB), operated by an experienced technician every 30 d. Ultrasound images were generated using an Aloka 500 V (Aloka Co., Ltd, Wallingford, CT) B-mode instrument equipped with a 3.5-MHz, 125 mm general-purpose transducer array (UST-5011U-3.5). Images were collected by a technician with software from the Cattle Performance Enhancement Company (CPEC, Oakley, KS). Estimates of UMARB were based on image analysis programming (Brethour, 1994) contained within the CPEC software program. Individual steers were harvested when UMARB indicated a score of 500 or greater, equivalent to low Choice or better quality grade. Steers were harvested at the Oregon State University Clark Meat Science Laboratory with carcass measurements collected 72 h post-harvest (−1 to 0 °C). The KF and OMF were collected for fatty acid analysis. They were placed in aluminum foil pockets, immediately placed in liquid nitrogen (−20 °C), and then stored in a freezer (−20 °C) until shipment to Washington State University. Rib sections (9th–11th rib) were removed from the right side of carcasses, vacuum-packaged and shipped to Washington State University along with the fat tissues described above.

At Washington State University Meat Laboratory two 1.3-cm thick steaks were sliced from the cranial end of each rib section. The second steak was used to collect muscle tissue, seam (intermuscular) and s.c. fat for fatty acid analysis. Then two 2.54-cm thick ribeye steaks were sliced from each rib section for sensory evaluation and SSF measurement. All the samples were kept frozen at −18 °C until measurement.

Table 1
Diet composition and nutrient analysis of growing and finishing diets.

	Growing diets[a]		Finishing diets[b]	
	G1	G2	F70	F85
Ingredient, %				
Ground grass hay	29.9	29.6	30.0	15.0
Rolled corn	9.8	27.4	43.1	56.6
Protein pellet[c]	30.1	22.8	24.5	26.2
Soybean hulls (pelleted)	30.2	20.2	–	–
Molasses	–	–	4.1	4.0
Nutrient[d]				
Dry matter, %	87.3	85.9	88.3	88.0
Crude protein, %	14.6	13.1	13.4	13.5
NDF, %	38.6	32.5	18.4	9.2
ADF, %	24.1	19.7	9.7	4.9
Ash, %	10.1	8.9	8.8	8.2
NEg, Mcal/kg	1.03	1.06	1.12	1.22

[a] G1 = Growing phase 1 diet; G2 = Growing phase 2 diet.
[b] F70 = Finishing diet with 70% concentrate; F85 = Finishing diet with 85% concentrate.
[c] Contained 1.9% non-protein nitrogen (urea) and 205 g Rumensin sodium per ton of supplement.
[d] Based on laboratory analysis.

2.2. Sensory evaluation and slice shear force

Frozen steaks were thawed at 3–4 °C for 48 h, weighed and then cooked on a preheated (175 ± 3 °C) George Foreman grill (model GR12; Salton, Miramar, FL). Geometric center temperature was monitored by a 12-Channel Scanning Thermocouple Thermometer (Model 692–8010, Barnart, Barrington, IL). Steaks were turned when the internal temperature reached 40 °C and removed at 71 °C (3.5–4° of doneness; Romans, Costello, Carlson, Greaser, & Jones, 2001). Steaks were weighed again and then SSF was determined by using a method adapted from that described by Wheeler, Shackelford, and Koohmaraie (2007). A 5-cm long slice was collected from the lateral end of each steak. Slices were cooled to room temperature (22 °C) and measured on a Warner-Bratzler Meat Shear (G-R Manufacturing, Manhattan, KS) fitted with a blade designed for SSF. The slices were positioned so that they would be sheared in the center, perpendicular to the muscle fibers along the 5-cm dimension of the slices. The remainder of the steak was trimmed of visible connective and fat tissue, cut into 1 × 1 × 2.5 cm pieces and then served warm to the sensory panel.

An eight-member trained sensory panel evaluated the palatability attributes of beef steaks (AMSA, 1995). Samples were randomly assigned to five sessions, with two controls present in every session. The quality grades of these two controls were similar to the Jersey beef samples, with one graded Low Choice and the other one Average Choice. Six warm samples per session were served to panelists in individual booths under fluorescent light (616 ± 16 lx, measured by a Traceable Dual-range Light Meter, Control, Friendswood, TX). Steaks were evaluated for initial tenderness, aroma, off-aroma, flavor, off-flavor, juiciness, and sustained tenderness on 10-cm unstructured line scales labeled at each end (Stone & Sidel, 1985). Each panelist was supplied unsalted crackers to cleanse the palate, distilled water to rinse, and a cup for expectoration. A ruler was used to determine the panelists' scores and the results were expressed in centimeters.

2.3. Fatty acid methyl ester synthesis and fatty acid analysis

Fatty acid methyl ester (FAME) formation was prepared according to O'Fallon, Busboom, Nelson, and Gaskins (2007). One milliliter of C13:0 internal standard (0.5 mg C13:0/ml MeOH), 0.7 ml 10 N KOH in water, and 5.3 ml MeOH were added to the samples. Then tubes were incubated in a 55 °C water bath for 1.5 h with vigorous hand-shaking for 5 s every 20 min. After the tubes were cooled below room temperature in a cold tap water bath, 0.58 ml 24 N H_2SO_4 in water was added. Tubes were mixed by inversion and incubated at 55 °C again with precipitated K_2SO_4 present. After FAME synthesis, tubes were cooled in a cold tap water bath. Then 3.0 ml of hexane was added and the tubes were vortex-mixed and then centrifuged for 5 min. The hexane layer, containing the FAME, was transferred into 2 ml gas chromatography (GC) vials. The vials were capped and stored at −20 °C until GC analysis. The fatty acid composition of FAME was determined by capillary GC on a SPTM-2560, 100 m × 0.25 mm × 0.20 μm capillary column (Supelco, Bellefonte, PA) installed on a Hewlett Packard 5890 GC (Hewlett Packard, Farmington Hills, MI). Initial oven temperature was 140 °C held for 5 min, then the temperature was increased to 240 °C at a rate of 4 °C min^{-1} and held for 20 min. Helium was used as the carrier gas at a flow rate of 0.5 ml min^{-1} and column head pressure was 280 kPa. Both the injector and detector were set at 260 °C. The split ratio was 30:1. Fatty acids were identified by comparing their retention times to those of methylated fatty acid standards (Nu-Chek Prep Inc., Elysian, MN). Total fatty acid concentration was expressed by mg/g of tissue and individual fatty acid by % of total fatty acids.