NRC Research Press

ARTICLE

Effects of forage finishing methods with alfalfa on cattle growth performance and beef carcass characteristics, eating quality, and nutrient composition

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Abstract: Over 2 yr, yearling steers ($n = 200$) were used to evaluate growth performance, carcass, meat quality, and nutrient composition traits as affected by management regimen comparing three methods of forage finishing (alfalfa pasture, hay, and silage) versus a high corn diet. Management regimen × year interactions ($P < 0.01$) for average daily gain, dry matter intake, gain-to-feed, carcass weight, and grade fat were due to lower performance for hay-fed cattle in years 1 vs. 2. Carcass, meat quality, and taste panel traits were generally similar ($P > 0.10$) across method of forage finishing. Trained taste panels found *longissimus* muscle from grain-fed beef to be more ($P < 0.01$) tender, juicy, and flavourful than forage finished beef, with lower ($P \leq 0.05$) ratings for tenderness and juiciness for hay- vs. silage-finished beef. Corn finished beef contained greater amounts of oleic and monounsaturated fatty acids and lower amounts of omega-3 and polyunsaturated fatty acids than forage finished beef ($P \leq 0.04$). Although the method of forage finishing may not affect most performance, carcass, and meat quality (pH, colour, intramuscular fat content, and shear force) traits, there may be concerns with tenderness and juiciness for beef from cattle finished on alfalfa hay.

Key words: beef cattle, alfalfa, forage finishing, tenderness, omega-3 fatty acids.

Résumé : Sur une période de 2 ans, des bouvillons d'un an ($n = 200$) ont été utilisés afin d'évaluer les caractéristiques de performance de croissance, de carcasse, de qualité de viande, et de composition d'éléments nutritifs selon les effets du régime de gestion en comparant 3 méthodes de finition à fourrage (pâturage de luzerne, foin, ensilage) par rapport à une diète à forte teneur en maïs. Les interactions de régime de gestion × année ($P < 0{,}01$) pour le gain moyen quotidien, la consommation de matières sèches, l'indice de consommation, poids de carcasse, et cote de gras étaient imputables à une moins bonne performance chez les bovins ayant reçu le foin dans l'année 1 contre l'année 2. Les caractéristiques de carcasse, de qualité de viande, et jury de dégustation étaient généralement semblables ($P > 0{,}10$) dans toutes les méthodes de finition à fourrage. Des jurys de dégustation d'expérience ont trouvé que le muscle *longissimus* provenant des bovins nourris aux grains était plus ($P < 0{,}01$) tendre, juteux, et savoureux que celui provenant des bovins avec finition à fourrage, avec de plus faibles cotes ($P \leq 0{,}05$) pour la tendreté et la jutosité des bovins avec finition à foin contre ensilage. Les bovins finis au maïs contenaient de plus grandes quantités d'acide oléique et d'acides gras mono-insaturés et de plus faibles quantités d'oméga-3 et d'acides gras polyinsaturés que les bovins avec finition à fourrage ($P \leq 0{,}04$). Tandis que la méthode de finition à fourrage n'a pas d'effet sur la plupart des caractéristiques de performance, de carcasse, et de qualité de viande (pH, couleur, teneur en gras intramusculaire, force de cisaillement), il pourrait y avoir des préoccupations par rapport à la tendreté et la jutosité du bœuf provenant des bovins finis au foin de luzerne. [Traduit par la Rédaction]

Mots-clés : bovins à bœuf, luzerne, finition à fourrage, tendreté, acides gras oméga-3.

Received 4 July 2019. Accepted 21 January 2020.

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Introduction

Grass-fed beef can be produced using various forage management systems that can differ in productivity, profitability, and environmental sustainability (Bhandari et al. 2015). There is a growing consumer demand for grass-fed beef due to their perceptions regarding the benefits from consuming grass-fed vs. commodity grain-fed beef from human health, environmental, animal welfare, and local production perspectives (Gillespie et al. 2016). More recently, Qushim et al. (2018) cited studies where 20%–30% of American beef consumers would pay a premium for grass-fed beef, along with noting the growing demand for alternative beef production including grass-fed, organic, and natural beef products. In Canada, Turner et al. (2015) noted the growth in niche market beef products at retail with the availability of alternative beef products with greater amounts of polyunsaturated fatty acids (PUFA) than conventional grain finished beef. Since the late 90s, numerous studies have found that forage finishing using pasture or conserved forages markedly increased the omega-3 fatty acid concentration of beef relative to beef conventionally finished on high grain diets (French et al. 2000; Realini et al. 2004; Purchas et al. 2005; Faucitano et al. 2008). In addition, past studies have also found that forage finishing increased concentrations of conjugated linoleic acid (CLA), a fatty acid produced from microbial fermentation that may have anticarcinogenic properties for humans (Shantha et al. 1995; Faucitano et al. 2008).

Although the Canadian Food Inspection Agency does not define grass-fed beef, the Federal Register in the US (USDA 2007) has defined grass-fed ruminant livestock production based on ruminants fed grass and forage throughout their life (with the exception of feeding milk pre-weaning) with no feeding of grain and grain by-products. The grass and forage can be fed as pasture or as conserved forage (balage, haylage, hay, and silage), browse, or crop residue without grain. This definition of grass-fed beef is important in Canada due to limited availability of high-quality pasture throughout the year depending on region, season, and growing conditions. Thus, grass-fed beef production in Canada may have to rely on feeding conserved forages at least for some time during the year. Recent studies have primarily focused on using pasture for grass-fed beef production in which the research compared growth, carcass, palatability, and nutrient composition traits to those from grain-fed beef. There is limited data evaluating grass-fed beef production using conserved forages in recent years. Although past studies have compared various types of forage finishing (pasture, hay, and silage) vs. high grain finishing on performance, carcass, meat quality, and nutrient composition traits, there are limited studies comparing method of forage finishing on a comprehensive evaluation of performance and product quality traits. The objectives of the current study were to examine how the method of forage finishing with alfalfa affects growth performance, carcass characteristics, eating quality, and nutrient composition in forage- vs. corn-finished beef.

Materials and Methods

Animals and management

This study was approved by the University of Guelph's Animal Care Committee in accordance with Animal Utilization Protocol No. 10R018 and guidelines of the Canadian Council of Animal Care (CCAC 1993). The study was conducted at the University of Guelph's New Liskeard research station located in New Liskeard, ON, Canada. In each year of a 2 yr study, 100 yearling steers with British breeding (Angus, Hereford, and crossbreds) were purchased in mid-May from commercial operations. The cattle were then allocated to one of four management regimens (MR) (approximately 24–28 head per MR subclass) based on forage or grain finishing: (1) alfalfa pasture, (2) alfalfa hay, (3) alfalfa silage, or (4) 85% concentrate diet based on whole shelled corn. The alfalfa hay and silage were produced from first cut in the previous year from fields that were similar to the fields used for pasture grazing. The 85% concentrate diet was based on whole shelled corn [77.3% of the diet on a dry matter (DM) basis], alfalfa/grass hay (15% on a DM basis), and a commercial 32% crude protein (CP) supplement (7.7% on a DM basis) which contained Rumensin. Drylot steers were allocated to pens equipped with Calan gates (four head per pen with cattle fed a common diet in each pen) to enable determination of feed intake for individual animals or to pens where cattle were group fed (six head per pen) with only pen feed intake data being available. Individual steer feed intake data per year included 24 head fed the 85% concentrate diet (six pens), 16 head fed the alfalfa silage diet (four pens), and 16 head fed the alfalfa hay diet (four pens). There were 12 head per group fed for each of the conserved forages (two pens per diet). For cattle fed the 85% concentrate diet, they were gradually adjusted from a 35% whole shelled corn, 57.2% alfalfa hay, 7.8% protein supplement diet to the final diet over 20 d. Pastured cattle were strip grazed on a mostly alfalfa pasture with two replicates (12–13 head per paddock). All forage finished cattle received a Rumensin controlled release capsule bolus (Elanco Animal Health, Division of Eli Lily, Guelph, ON, Canada) for bloat prevention and performance benefits. All cattle received a vitamin and mineral premix containing 14% calcium, 6.5% phosphorus, 7.8% sodium, 1% magnesium, 720 mg kg^{-1} cobalt, 960 mg kg^{-1} copper, 5760 mg kg^{-1} iron, 50 mg kg^{-1} fluorine, 3200 mg kg^{-1} manganese, 24 mg kg^{-1} selenium, 4000 mg kg^{-1} zinc, 320 kIU kg^{-1} vitamin A, 48 kIU kg^{-1} vitamin D, 800 IU kg^{-1} vitamin E (Masterfeeds F-C Pasture Mineral; Master Feeds, London, ON, Canada) on a daily basis, whereas cattle on pasture received bloat guard (Bio Agri Mix, Mitchell, ON, Canada) mixed in the mineral mix as a bloat preventative. The cattle were weighed on two consecutive days at the start and end of the trial and every 28 d throughout the study. The study ended each year (mid to late September) when there was no longer enough alfalfa pasture to meet the needs of pastured cattle. Average daily gain (ADG) was determined for all cattle in the trial, whereas feed intake and feed-to-gain data were determined for all cattle housed in pens equipped with Calan gates.

Feed analysis

Feed samples were collected bi-weekly and DM content was determined by oven drying at 60 °C for 48 h. Dried feed samples were then ground through a Wiley mill (Arthur H. Thomas, Philadelphia, PA, USA) using a 1 mm screen, composited by month, and submitted to a commercial feed laboratory (Agri-Food Laboratories, Guelph, ON, Canada) for further analysis. Feed nitrogen (N) concentration was determined using a Leco N analyzer (Leo Corporation, St. Joseph, MI, USA), and CP was calculated by multiplying 6.25 by percent feed N. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to the method of Van Soest et al. (1991) using an ANKOM 2000 fibre analyzer (ANKOM Technology Corp., Fairport, NY, USA) with sodium sulfite being used in the NDF analysis. Determination of major minerals (calcium, phosphorus, potassium, sulfur, magnesium, and sodium) and trace minerals (copper, iron, manganese, zinc) was based on inductively coupled plasma optical emission spectrometry (PerkinElmer, Woodbridge, ON, Canada) according to AOAC (2007) method 985.01. Nutrient composition and fatty acid content of diets and feedstuffs are presented in Table 1.

Cattle slaughter and carcass processing

Cattle were marketed at common times on feed (107–121 d) such that approximately equal numbers of cattle per MR/breed subclass were shipped for a given slaughter date for processing at a commercial beef packing plant in Guelph, ON, Canada. There were three slaughter dates in year 1 and two slaughter dates in year 2. Due to death losses (four from bloat for pastured cattle and two deaths for alfalfa silage-fed cattle), light initial weights at the start of the trial in year 1, and poor performance for forage finished cattle, a total of 13 cattle from year 1 were not shipped for slaughter. This included the six death losses previously mentioned, one steer fed the high concentrate diet, four steers fed alfalfa hay, and two steers fed alfalfa silage. Cattle were handled and slaughtered according to industry procedures, including stunning with pneumatic captive bolt prior to exsanguination. The order of kill was recorded at the plant to enable identification of individual carcasses.

At approximately 84 h postmortem (PM), carcass sides were ribbed between the 12th and 13th ribs and then graded by Canadian Beef Grading Agency (2017) graders according to Livestock and Poultry Carcass Grading Regulations (Canadian Food Inspection Agency 2018) to determine carcass grade and yield characteristics, including marbling score, lean yield, and quality grade. Camera data were collected on the split interface between the 12th and 13th ribs, including subcutaneous backfat (mm) and *longissimus* muscle area (LMA; cm^2) in the last quadrant over the *longissimus*. A bone-in rib (3×4 with chine bone on) containing all lean, muscle, and fat in ribs 6–12 from the *longissimus thoracis* (LT) (IMPS No. 107; NAMI 2014) in the forequarter and a semitendinosus (ST) muscle (IMPS No. 171C; NAMI 2014) from the hindquarter were removed from the right side of each carcass, packaged and shipped to the University of Guelph Meat Laboratory for further processing.

At 5 d PM, rib sections were weighed, with eight bone-in LT steaks approximately 3.2 cm in thickness fabricated from each rib section. The first six steaks from each rib section were dissected into lean, fat, and bone components with each component weighed and data recorded along with partitioning fat into subcutaneous, intermuscular, and body cavity fat depots using a modification of the procedure described by Lunt et al. (1985). Boneless LT steaks were allocated for meat quality evaluation with steak 1 being used for determination of colour, pH, qualitative and quantitative fatty acid composition, and intramuscular fat (IMF) content, whereas steaks 2 and 3 were aged for 14 d for assessment of palatability attributes by a trained taste panel. Steaks 4–6 were aged for 7, 14, and 21 d, respectively, at ≤4 °C prior to Warner–Bratzler shear force (WBSF) evaluation for an instrumental assessment of tenderness. Steak 7 was used to determine the extent of lipid oxidation using the thiobarbituric acid reactive substances (TBARS) assay.

Semitendinosus muscles were trimmed of excess fat and connective tissue, cut into five 2.5 cm thick steaks, individually labeled and vacuum sealed. Semitendinosus steaks 1–5 were allocated for meat quality evaluation in an identical manner as LT steaks 1 and 4–7 for determination of colour, pH, qualitative and quantitative fatty acid composition, shear force, and extent of lipid oxidation. Post-ageing, both *longissimus* muscle (LM) and ST steaks were frozen at −22 °C for storage until analysis.

Meat quality evaluation

Temperature and pH measurements were measured on 5 d aged steaks using a Hanna spear-tipped pH electrode (Hanna Instruments, Mississauga, ON, Canada) equipped with a thermocouple connected to an Accumet A71 pH meter (Fisher Scientific, Toronto, ON, Canada) using the methods described by Streiter et al. (2012).

Meat colour reflectance coordinates (Commission International de l'Eclairage 1976) L^* (brightness), a^* (red-green axis), and b^* (yellow-blue axis), were measured on 5 d aged steaks at six locations on the surface

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Table 1. Nutrient composition and fatty acid content for diet components (DM basis).

	Year 1							Year 2						
		Alfalfa							Alfalfa					
Item	Corn TMR	Pasture	Hay	Silage	Whole shelled corn	TMR hay	Protein supplement	Corn TMR	Pasture	Hay	Silage	Whole shelled corn	TMR hay	Protein supplement
DM (%)	92.9	30.0	93.0	52.3	93.7	92.5	94.7	93.7	27.2	92.5	52.3	94.6	92.3	94.2
CP (%)	12.4	18.6	13.4	17.5	8.0	14.6	41.7	13.0	15.9	13.8	14.3	8.1	11.2	40.4
NDF (%)	21.6	37.9	46.5	39.1	11.6	36.5	23.0	30.0	42.2	45.2	46.8	15.8	63.4	24.1
ADF (%)	10.7	28.3	34.5	32.1	2.8	26.8	9.9	17.3	30.5	32.9	35.4	4.4	45.5	11.5
NE_m (Mcal kg^{-1})[a]	2.34	1.54	1.39	1.47	2.41	1.57	2.37	1.86	1.47	1.44	1.38	2.32	0.99	2.32
NE_g (Mcal kg^{-1})[a]	1.63	0.94	0.81	0.88	1.69	0.97	1.66	1.22	0.88	0.80	0.80	1.6	0.44	1.61
Ca (%)	0.58	1.68	1.52	1.88	0.02	1.40	3.57	0.62	1.43	1.36	0.99	0.08	0.75	3.28
P (%)	0.33	0.25	0.24	0.28	0.28	0.21	1.03	0.35	0.24	0.21	0.24	0.28	0.18	0.99
Fatty acids	**g 100 g^{-1} of total fatty acids**							**g 100 g^{-1} of total fatty acids**						
Myristic C14:0	0.26	0.96	1.33	1.15	0.04	1.23	NA	0.29	0.79	1.65	1.20	0.03	1.25	NA
Palmitic C16:0	15.8	27.0	33.4	26.8	12.0	26.9	NA	17.7	21.2	27.8	25.3	12.0	35.1	NA
Palmitoleic C16:1	0.34	0.65	0.34	0.31	0.11	0.35	NA	0.14	2.09	1.90	0.322	0.035	1.19	NA
Heptadecanoic C17:0	0.18	0.57	0.99	0.57	0.06	0.66	NA	0.38	0.39	0.67	0.54	0.06	0.82	NA
Stearic C18:0	2.5	3.5	4.5	4.3	1.4	3.2	NA	3.2	3.6	4.9	4.4	1.4	5.8	NA
Oleic *cis* 9 C18:1	23.9	3.1	4.5	4.6	24.5	3.3	NA	28.3	2.8	3.0	4.2	25.8	5.3	NA
Vaccenic *cis* 11 C18:1	0.95	0.77	0.50	0.49	0.65	0.41	NA	0.30	0.37	0.42	0.56	0.06	1.44	NA
Linoleic C18:2	49.3	19.7	19.6	19.5	59.5	19.2	NA	45.9	19.8	20.5	20.9	58.6	21.4	NA
ϒ-Linolenic C18:3n6	0.06	0.36	0.30	0.32	0.00	0.35	NA	0.05	0.32	0.27	0.32	0.00	0.43	NA
α-Linolenic C18:3*n*3	5.9	40.9	30.5	39.5	1.4	42.1	NA	2.2	45.7	33.7	37.3	1.2	19.1	NA
Eicosatrienoic C20:3	0.07	0.38	0.35	0.35	0.00	0.32	NA	0.05	0.52	0.81	0.75	0.00	0.67	NA
Arachidonic C20:4	0.34	0.40	1.33	0.11	0.10	0.10	NA	0.10	1.04	1.32	1.45	0.10	2.18	NA
Eicosapentaenoic (EPA) C20:5	0.06	0.53	0.79	0.55	0.06	0.50	NA	0.05	0.30	0.59	0.50	0.06	0.89	NA
Docosatetraenoic C22:4	0.30	1.08	1.43	1.28	0.11	1.19	NA	0.29	0.95	1.33	1.48	0.14	2.13	NA

Note: DM, dry matter; TMR, total mixed ration; CP, crude protein; NDF, neutral detergent fibre; ADF, acid detergent fibre; NE_m, net energy maintenance; NE_g, net energy gain; Ca, calcium; P, phosphorus; NA, not available as no fatty acid analysis was conducted on the protein supplement. Corn TMR is the 85% concentrate TMR comprised (DM basis) of 77.3% whole shelled corn, 15% alfalfa hay (TMR hay), 32% CP supplement. Vitamin/mineral premix contained 14% Ca, 6.5% P, 7.8% sodium, 1% magnesium, 720 mg kg^{-1} cobalt, 960 mg kg^{-1} copper, 5760 mg kg^{-1} iron, 50 mg kg^{-1} fluorine, 3200 mg kg^{-1} manganese, 24 mg kg^{-1} selenium, 4000 mg kg^{-1} zinc, 320 kIU kg^{-1} vitamin A, 48 kIU kg^{-1} vitamin D, 800 IU kg^{-1} vitamin E (Masterfeeds F-C Pasture Mineral; Master Feeds, London, ON).

[a]Calculated according to NRC (1996).

of both LM and ST steaks following a 30 min bloom using a Minolta CR-400 colour meter with a light projection tube (22 mm disc) (Folio Instruments, Kitchener, ON, Canada), illuminant D65, and 0° viewing angle (Streiter et al. 2012). The a^* and b^* values were used to calculate hue angle [$H_{ab} = \arctan(b^*/a^*)^*(180/\pi)$] and chroma [$C_{ab} = (a^{*2} + b^{*2})^{0.5}$].

Cooked steaks for WBSF analysis were thawed for 48 h at ≤4 °C, trimmed of external fat and epimysium, and weighed prior to cooking. Steaks were cooked to an internal temperature of 70 °C using a Garland Grill (ED-30B; Garland Commercial Ranges Ltd., Mississauga, ON, Canada). Steak temperature was continually monitored using a Type K flexible high-temperature thermocouple (Omega, Laval, QC, Canada) inserted into the geometric centre of each steak. Steaks were turned when they reached an internal temperature of 40 °C. Cooked steaks were weighed, placed in individual bags, immediately chilled in ice water and stored at ≤4 °C for 24 h prior to shearing. Cooking losses were calculated using the initial raw and final cooked weights of each sample, using the equation {% cook loss = [(raw weight − cooked weight)/raw weight] × 100}.

Steaks were removed from the cooler and allowed to equilibrate to room temperature. Eight cores of 1.3 cm diameter were removed parallel to the muscle fibres from each steak using a drill press mounted corer (Mastercraft 10 in Drill Press). Cores were sheared using a Warner–Bratzler blade attached to a TA-XT Plus texture analyzer (Texture Technologies Corp., Scarsdale, NY, USA) with a cross-head speed of 3.3 mm s^{-1}. Peak shear force was determined using a custom pre-programmed macro in Stable Microsystems Texture Exponent software (Stable Microsystems Ltd, ME, USA), with the average of eight shear force values for a given steak used in data analysis as the shear force value for each animal.

Shelf life was determined on 14 d aged LT and ST steaks, pre-weighed onto 17S Styrofoam® trays with soaker pads (Shortreed, Guelph, ON, Canada), overwrapped with oxygen permeable commercial polyvinyl chloride film and stored in a cooler with the lights on for 4 d at ≤4 °C to determine drip loss. Shelf-life steaks were processed for pH, temperature, and objective colour as previously described, vacuum packaged, and frozen at ≤−22 °C until further analysis. Thiobarbituric acid reactive substances [malonaldehyde (MDA) content] analysis on shelf-life steaks was determined according to Botsoglou et al. (1994). Sample absorbance was read using a Shimadzu UV–Vis spectrophotometer (Shimadzu Corporation, Kyoto, Japan) at 532 nm. Absorbance was plotted against standard concentrations of MDA (ng MDA) with values expressed as ng MDA g^{-1} of meat sample.

Determination of IMF content, fatty acid composition, and vitamin B_{12} analysis

Seven day aged LT and ST steaks were thawed at ≤4 °C for 24 h, trimmed of external fat and epimysium, and cubed for freeze-drying. Freeze-dried samples were ground in a coffee grinder and then mixed. Dry matter was determined from the difference in weight before and after freeze-drying and corrected by oven-drying at 100 °C. Intramuscular fat content (crude fat) was determined by petroleum ether extraction using the Ankom XT20 Fat Analyzer (Ankom Technology Corp., Fairport, NY, USA).

Freeze-dried feed and muscle samples were extracted for fatty acid determination using methods described by Berthiaume et al. (2015), with fatty acid methyl esters being determined using a Shimadzu 2014 gas chromatograph equipped with a Shimadzu AOC-20 auto sampler and a 120 m × 0.25 mm × 0.25 μm BPX-70 capillary column (Mandel Scientific, Guelph, ON, Canada). Helium was used as the carrier gas with a 20:1 split ratio. Injector temperature was 250 °C, whereas flame ionization detector temperature was 280 °C. Initial oven temperature was 150 °C which was held for 1 min, then increased to 180 °C at a rate of 10 °C min^{-1}, from 180 to 200 °C at 2 °C min^{-1}, and from 200 to 240 °C at 1 °C min^{-1} and held for 2 min. Fatty acid methyl esters of samples were identified by comparison of retention times to that of gas chromatography reference standards (Nu-Check-Prep, Elysian, MN, USA). Chromatograms were integrated using Shimadzu GC solutions software.

Vitamin B_{12} content of LT and ST muscles was determined according to the method described by Girard et al. (2007).

Sensory evaluation

Two sensory panels were conducted to evaluate palatability attributes of LT steaks from the 2 yr study. Procedures for the taste panels were approved by the University of Guelph Research Ethics Board for compliance with federal guidelines for research involving human participants. Informed, written consent was obtained from each participant before the start of screening. Potential panelists for the trained taste panel were screened over the course of 2 d, and 10 panelists were chosen to participate in the evaluation of LT steaks. Panelists were trained for 8 d based on procedures outlined by AMSA (2015). Each year, 16–17 steaks were randomly chosen from each MR for taste panel evaluation. Taste panel evaluations were conducted in one 45 min session per day for 4 d wk^{-1} over a 5 wk period.

Steaks were prepared for sensory panel evaluation following the procedures described by Streiter et al. (2012). Steak samples were evaluated using a 10 cm line with verbal intensity descriptors as anchors based on quantitative descriptive analysis (Stone and Sidel 2003) for the following palatability traits: softness, tenderness, initial juiciness, beef flavour, grassy flavour, off flavour, chewiness, overall juiciness, flavour desireablitiy, and overall acceptability.

Each panelist received two cores per steak and six samples per session. Assessment of palatability attributes was conducted within 1 h post-cooking of steaks in a sensory booth equipped with red lighting. Water and unsalted crackers were supplied during both the training and testing sessions to cleanse the palate between samples.

Statistical analysis

Growth performance, feed intake, carcass, meat quality, sensory evaluation, and nutrient composition data were analyzed with a mixed linear model (PROC GLIMMIX) in SAS version 9.4 [SAS Institute Inc. (2012); Cary, NC, USA] using a completely randomized design. The model included the fixed effects of MR and year and the MR × year interaction. Pen, breed, and location were included as random effects with animal as the experimental unit. Date of slaughter was also included as a random effect for all carcass and meat quality data. Initial steer body weight (BW) was included as a covariate for growth performance data [ADG, DM intake (DMI), gain-to-feed (G:F)], but was removed from the final models for ADF and G:F because the P values for the covariate were greater than 0.05. Each analyzed variable were subjected to four covariance structures: compound symmetry, variance components, autoregressive order 1, and unstructured. The covariance structure with the smallest Akaike information criterion (variance components) was used for statistical interpretation of the data. Differences among MR means were determined using the following orthogonal contrasts: (1) corn finished steers vs. steers finished on forage (pasture, hay, and silage); (2) pasture finished vs. steers finished on conserved forages (hay and silage); and (3) hay vs. silage finished steers. Shear force and cooking loss data were analyzed using a mixed linear model (PROC GLIMMIX) which included the fixed effects of MR, year, day of aging, and all two- and three-way interactions. Statistical differences were considered significant at $P < 0.05$.

Results and Discussion

Growth performance

The alfalfa used in this study (pasture, hay, and silage) along with the alfalfa/grass hay used for the corn total mixed ration (TMR) was grown on similar soils at the New Liskeard Agricultural Research Station. Across the 2 yr in the study, protein content and net energy maintenance (NE_m) were greatest in alfalfa pasture, intermediate in alfalfa silage, and lowest in alfalfa hay (Table 1). This corresponds to NDF values that were lowest in alfalfa pasture, intermediate in alfalfa silage, and greatest in alfalfa hay. The corn TMR contained the greatest amount of energy (NE_m and NE_g) compared to any method of forage finishing due to much lower NDF and ADF concentrations. However, the corn TMR contained the lowest amount of CP. There were year differences in the NDF, ADF, and CP levels for alfalfa pasture and alfalfa silage, with lower-quality forage being fed in year 2 of the study. Crude protein, NDF, and ADF values were similar between years for alfalfa hay (Table 1).

There were no differences ($P > 0.58$; data not presented) in BW at the start of the trial across MR. Management regimen × year interactions ($P < 0.001$) were present for all growth performance traits (ADG, DMI, G:F; Table 2). These interactions are most likely explained by year differences in DMI for cattle fed alfalfa hay vs. silage diets due to the effects of DMI on gains and feed conversion. Although hay-fed cattle consumed more ($P < 0.001$; contrast 3) DM (kg d^{-1}, % BW bases) in years 2 vs. 1, the converse was true for silage-fed cattle. The interactions may also be due to differences in energy and protein contents between the forages across the 2 yr of the study as previously described (Table 1). In addition, year 1 alfalfa hay tended to be dustier than year 2 hay when ground, and this may partially explain the lower DMI for cattle fed alfalfa in year 1. The MR × year interaction for differences in conserved forage intakes is at least partially responsible for the remaining MR × year interactions ($P < 0.01$) and most corresponding contrasts ($P \leq 0.07$) were applicable for final weight, total weight gain, ADG, DMI, and G:F. The interaction for DMI between corn and forage finished cattle can also be explained by year to year differences in DMI for grain-fed cattle due to year differences in BW at the start of the trial, with DMI being greater in the lighter weight grain-fed cattle in year 1 vs. DMI for heavier weight cattle in year 2.

There is limited information in the scientific literature examining methods of forage finishing for grass-fed beef production. Cattle performance in past studies contradict findings in the present study when examining cattle fed timothy hay or silage (Petit and Flipot 1992), or cattle fed alfalfa pasture or alfalfa hay (Pordomingo et al. 2012*a*) with no effects of method of forage finishing on gains. Gains for cattle finished on alfalfa pasture in the present study are similar to Duckett et al. (2013), which exceeded the 0.93 kg d^{-1} ADG value reported by Scaglia et al. (2012) for cattle grazing alfalfa pasture. Growth performance differences between grain and alfalfa silage-fed cattle are similar to those reported by Mandell et al. (1997, 1998) when cattle were fed to a constant backfat endpoint. The key to maximizing grass-fed beef production is forage quality, as Schmidt et al. (2013) found that cattle could gain 1.28 kg d^{-1} on alfalfa pasture containing 26.3% CP, 28% NDF, which is superior to the nutrient composition for alfalfa pasture used in the present study (Table 1). Although the dramatic increase in DMI between years for alfalfa hay-fed cattle led to major year differences in ADG and G:F (Table 2), Oltjen et al. (1971) and Pordomingo et al. (2012*a*) both found that cattle can consume alfalfa hay at over 3% of BW, which exceeds DMI at 2.23% of BW in the present study for alfalfa hay-fed cattle gaining 1.32 kg d^{-1} in year 2 of the present study. The drastic year to year differences in ADG for cattle fed alfalfa hay are

Table 2. MR × year interactions for growth performance traits.

			MR					*P* for contrasts			
				Method of finishing on alfalfa				*P*	1	2	3
Item	Covariate initial weight	Year	Corn finished	Pasture	Hay	Silage	SEM	MR × year interaction	Corn vs. forage	Pasture vs. hay and silage	Hay vs. silage
Number of head	—	1	23	21	21	21	—	—	—	—	—
	—	2	24	26	24	25	—	—	—	—	—
Initial weight (kg)	—	1	410.8	404.8	422.8	412.7	7.50	0.49	0.68	0.18	0.49
	—	2	431.5	441.3	438.1	437.6	—	—	—	—	—
Final weight (kg)	—	1	598.7	531.2	508.3	525.4	8.22	<0.001	0.90	0.238	<0.001
	—	2	639.7	562.6	589.3	540.7	—	—	—	—	—
Total gain (kg)	—	1	188.6	126.5	86.7	114.4	4.45	<0.001	0.66	<0.001	<0.001
	—	2	208.1	120.9	152.2	104.1	—	—	—	—	—
ADG (kg d^{-1})	<0.001	1	1.82	1.09	0.77	1.00	0.04	<0.001	0.01	<0.001	<0.001
	—	2	1.81	1.09	1.32	0.92	—	—	—	—	—
DMI (kg d^{-1})	<0.001	1	11.31	NA	9.14	10.59	0.44	<0.001	<0.041	NA	<0.001
	—	2	10.52	NA	11.12	8.69	—	—	—	—	—
DMI (% body weight)	0.001	1	2.18	NA	1.97	2.19	0.09	<0.001	0.07	NA	<0.001
	—	2	1.99	NA	2.23	1.83	—	—	—	—	—
G:F (kg gain kg^{-1} of DMI)	—	1	0.16	NA	0.08	0.10	0.005	<0.001	0.18	NA	<0.001
	—	2	0.17	NA	0.12	0.10	—	—	—	—	—

Note: MR, management regimen; SEM, standard error mean; ADG, average daily gain; DMI, dry matter intake; G:F, gain to feed; NA, not applicable due to lack of DMI data for cattle managed on pasture. Management regimen includes cattle finished on high grain corn diet (corn) or forage finished using alfalfa pasture (pasture), alfalfa hay (hay) or alfalfa silage (silage). Contrasts: 1 = corn vs. forage finished cattle by year; 2 = pasture vs. the average of hay and silage finished cattle by year; 3 = hay vs. silage finished cattle by year. Covariate, initial start of test weight (kg) was included in the model for growth performance traits where appropriate and was kept in the final model when $P < 0.05$.

important for producers producing "grass-fed" beef as any factor affecting DMI will most likely affect ADG, G:F, time on feed, and potential profitability. Beef producers need to take nutrient composition into account when forage finishing, as forage quality will have a major influence on growth performance and time on feed regardless of how the forage is fed. However, nutrient composition data may not truly reflect forage digestibility and animal acceptability as Dierking et al. (2010) found that cattle only gained 0.3 kg d^{-1} consuming a tall fescue/alfalfa pasture containing 21.6% CP and 38.9% NDF, indicating forage quality that was superior to the alfalfa pasture fed in the present study.

Carcass traits

The greater rate of gain for cattle fed alfalfa hay in years 2 vs. 1 is most likely responsible for MR × year interactions ($P \leq 0.001$; contrasts 2 and 3) for hot carcass weight, dressing percentage, and grade fat comparing cattle that were forage finished (Table 3). For all three carcass traits, there is a greater difference in trait values between years for hay fed cattle than for pasture or silage finished cattle which can be attributed to much greater DMI and corresponding ADG in year 2 for hay-fed cattle as previously described. Pordomingo et al. (2002*a*) recognized the importance of gain on carcass traits as slower growing cattle fed alfalfa hay produced lighter carcasses with less back fat and smaller LMA than faster growing cattle fed alfalfa pasture. Hot carcass weights, dressing percentage, grade fat, and unadjusted LMA were greater for corn vs. forage finished cattle (data not presented), results which are supported by past studies in which trait values were greater in grain finished cattle vs. cattle finished on alfalfa pasture (McCaughey and Clipef 1996; Scaglia et al. 2012; Duckett et al. 2013). *Longissimus* muscle area adjusted to a 100 kg carcass weight basis was greater for forage vs. grain finished, with no trait differences across methods of forage finishing (data not presented). This is in contrast to Oltjen et al. (1971), where LMA was greater in alfalfa hay vs. grain finished cattle. Marketing grain and alfalfa silage fed cattle after a constant time on feed increased backfat for grain finished cattle without affecting carcass weight and LMA (Mandell et al. 1998).

For both years of the study, carcasses from most forage finished cattle qualified for the Canada "A" grade with at least 2 mm fat cover over the ribs along with adequate marbling and lean and fat colour. The greater rate of gain for cattle fed hay in years 2 vs. 1 along with the heavier BW at the start of the study in year 2 for all cattle are most likely responsible for an MR × year interaction ($P < 0.001$) for quality grade (Table 3). This led to greater increases in quality grade for cattle fed conserved forages in year 2, with smaller increases in quality grade for corn and pasture fed cattle which resulted in significant contrast effects for corn vs. forage finished cattle ($P < 0.01$; contrast 1) and pasture vs. conserved forage finished cattle ($P = 0.02$; contrast 2). Most cattle for each MR graded as Canada AA-marbled carcasses ranging from 47% for alfalfa silage-fed cattle to 75% for corn finished cattle, whereas there were a greater percentage of A-marbled carcasses with forage finished cattle ranging from 51% for alfalfa hay-fed cattle to <7% for corn finished cattle (data not presented). The limited amount of Canada AAA-marbled carcasses for corn-fed cattle (~19%) in the present study is most likely due to marketing of all cattle after a constant time on feed relative to the amount of pasture available in the study, and lighter live/carcass weights relative to commercial cattle currently being marketed across North America. There were some quality-grade problems with forage finishing in the present study. There was one Canada B1 carcass from an alfalfa silage fed steer that failed to grade due to inadequate backfat finish and (or) marbling and six dark cutters (Canada B4 grade) across the three methods of forage finishing for the 2 yr of the study. McCaughey and Clipef (1996) also noted grading concerns with pasture finishing cattle with over 81% of pasture finished carcasses grading as Canada A or B1 carcasses with limited amounts of marbling. This contrasts to American work where finishing cattle on alfalfa pasture produced USDA Select (Canada AA equivalence) carcasses (Scaglia et al. 2012; Schmidt et al. 2013). Grading concerns for forage finished cattle may not be an issue depending how producers market grass-fed beef.

Based on rib dissection data, MR × year interactions ($P < 0.01$) were found for percent carcass lean, fat, and bone with the most pronounced differences in lean and fat deposition in the rib for forage finished cattle fed hay in years 2 vs. 1 of the study (Table 3). Although this most likely explains the differences ($P = 0.05$; contrast 2) in lean content for cattle fed pasture vs. conserved forages, there were also major changes in lean, fat, bone content in the rib for corn-fed cattle, which is partially responsible for the interaction contrast ($P < 0.001$; contrast 1) for all body composition attributes comparing corn vs. forage finished cattle. Mandell et al. (1997) found that finishing cattle using alfalfa silage increased lean, fat, and bone yields vs. cattle finished on a high grain diet. Management regimen differences for rib dissection data support greater Canadian Beef Grading Agency lean yield and yield grade scores for forage finished vs. grain-fed cattle with no differences across method of forage finishing (data not presented). Lean yield values were lower (McCaughey and Clipef 1996), similar (Scaglia et al. 2012), or greater (Duckett et al. 2013) when comparing past studies evaluating pasture vs. grain finished beef.

Meat quality evaluation

Management regimen did not affect ($P \geq 0.12$) pH in LM and ST muscles (Table 4) a finding that is in agreement with past studies comparing LM pH between grain and

Table 3. MR × year interactions for carcass traits.

		MR						Contrasts		
			Method of finishing on alfalfa					1	2	3
Item	Year	Corn finished	Pasture	Hay	Silage	SEM	*P* for MR × year interaction	Corn vs. forage	Pasture vs. hay and silage	Hay vs. silage
Hot carcass wt (kg)	1	340.3	295.5	258.7	274.4	17.82	<0.001	0.42	0.002	<0.001
	2	358.3	306.5	308.9	279.3	—	—	—	—	—
Dressing (%)	1	56.8	55.9	50.4	51.9	0.97	<0.001	0.09	0.003	0.003
	2	55.9	54.6	52.4	51.7	—	—	—	—	—
Grade fat (mm)	1	15.0	7.8	4.9	6.4	1.58	<0.001	0.87	<0.001	0.01
	2	15.7	6.0	9.0	6.9	—	—	—	—	—
Quality grade[a]	1	2.04	1.52	1.38	1.35	0.25	<0.001	0.002	0.02	0.33
	2	2.08	1.79	1.99	2.16	—	—	—	—	—
Carcass lean (%)	1	48.8	55.3	59.3	57.5	1.47	<0.001	<0.001	0.05	0.32
	2	52.6	52.9	52.9	52.9	—	—	—	—	—
Carcass fat (%)	1	31.1	20.9	15.2	17.2	1.81	<0.001	<0.001	0.007	0.18
	2	23.7	22.1	23.7	22.4	—	—	—	—	—
Carcass bone (%)	1	19.4	23.4	25.0	24.7	0.85	<0.001	<0.001	0.01	0.14
	2	23.5	24.9	23.4	24.6	—	—	—	—	—

Note: MR, management regimen; SEM, standard error of the mean. Management regimen includes cattle finished on high grain corn diet (corn) or forage finished using alfalfa pasture (pasture), alfalfa hay (hay) or alfalfa silage (silage). Contrasts: 1 = corn vs. forage finished cattle by year; 2 = pasture vs. the average of hay and silage finished cattle by year; 3 = hay vs. silage finished cattle by year.

[a]For statistical analysis of quality-grade data, data were first transformed into numerical data for statistical analysis. Prime = 4, AAA = 3, AA = 2, A = 1, and a 0 was given for any B grade (B1, B2, B3, and B4).

Table 4. Effect of method of forage finishing on meat quality evaluation of LM and ST as compared with corn finished cattle.

	MR								*P* for contrasts		
		Method of finishing on alfalfa				*P* for ANOVA[a]			1	2	3
Item	Corn finished	Pasture	Hay	Silage	SEM	MR	Year	MR × year interaction	Corn vs. forage	Pasture vs. hay and silage	Hay vs. silage
LM evaluation											
pH	5.55	5.56	5.59	5.57	0.03	0.08	0.88	0.08	0.09	0.14	0.15
L^*	35.9	35.9	35.8	36.3	0.67	0.61	0.29	0.19	0.83	0.89	0.13
Chroma	20.1	19.2	18.9	19.0	0.24	0.28	0.03	0.61	0.005	0.49	0.69
Hue angle	12.6	11.6	10.9	11.7	0.71	0.42	0.34	0.79	0.04	0.75	0.23
Drip loss (%)	1.3	1.2	1.2	1.4	0.21	0.65	0.98	0.18	0.81	0.79	0.22
IMF (%)	4.14	2.60	2.68	2.81	0.62	0.009	0.08	0.04	0.006	0.78	0.64
Vitamin B_{12} (ng g^{-1})	47.8	44.4	39.7	44.5	6.00	0.33	0.22	<0.001	0.21	0.80	0.03
TBARS (ug MDA g^{-1})	0.53	0.62	1.13	1.09	0.26	0.006	0.002	<0.001	0.004	0.13	0.73
Shear force (kg)	3.63	3.96	3.93	3.87	0.36	0.28	0.06	0.98	0.08	0.84	0.78
Cooking losses (%)	19.9	20.4	20.6	20.9	0.47	0.08	0.10	0.06	0.07	0.48	0.32
ST evaluation											
pH	5.48	5.47	5.52	5.52	0.03	0.18	0.47	0.02	0.29	0.06	0.81
L^*	38.6	37.9	38.2	37.4	0.51	0.24	0.13	0.25	0.09	0.89	0.07
Chroma	22.7	21.2	21.1	20.7	0.35	<0.001	0.63	0.03	<0.001	0.32	0.22
Hue angle	18.9	17.4	16.6	15.1	0.97	<0.001	0.87	0.25	<0.001	0.01	0.04
Drip loss (%)	1.03	1.16	0.94	1.02	0.11	0.52	0.99	0.20	0.86	0.30	0.36
IMF (%)	2.73	1.94	1.85	1.79	0.17	0.18	0.18	0.06	<0.001	0.54	0.81
Vitamin B_{12} (ng g^{-1})	59.6	58.7	56.1	59.3	10.15	0.82	0.35	0.05	0.78	0.95	0.40
TBARS (ug MDA g^{-1})	1.11	1.19	1.64	1.59	0.37	0.02	0.002	0.02	0.02	0.17	0.75
Shear force (kg)	5.56	5.83	5.74	5.58	0.11	0.08	0.02	0.27	0.11	0.11	0.18
Cooking losses (%)	25.9	25.7	26.4	26.3	0.29	0.68	<0.001	0.28	0.46	0.47	0.95

Note: LM, *longissimus* muscle; ST, semitendinosus; MR, management regimen; ANOVA, analysis of variance; SEM, standard error of the mean; IMF, intramuscular fat; TBARS, thiobarbituric acid reactive substances; MDA, malonaldehyde content. Management regimen includes cattle finished on high grain corn diet (corn) or forage finished using alfalfa pasture (pasture), alfalfa hay (hay) or alfalfa silage (silage). Contrasts: 1 = corn vs. forage finished cattle; 2 = pasture vs. the average of hay and silage finished cattle; 3 = hay vs. silage finished cattle.

[a]ANOVA examines MR, year, and the MR × year interaction (MR × year).

forage finished cattle (Realini et al. 2004; Faucitano et al. 2008; Pordomingo et al. 2012*a*). This contrasts Duckett et al. (2013), where LM pH values were greater in pasture vs. grain finished beef. Although there was an MR × year interaction ($P = 0.02$) for ST pH for beef from cattle fed conserved forages (data not presented), all values ranged from 5.48 to 5.56 across the 2 yr in which all cattle were processed at the identical packing plant, which used low voltage electrical stimulation after exsanguination and high voltage electrical stimulation once carcasses entered the hot box.

Management regimen did not affect ($P \geq 0.24$) L^* values for LM or ST, a finding in agreement with past studies evaluating LM colour between forage and grain finished beef (French et al. 2000; Pordomingo et al. 2012*a*). Pasture finishing with alfalfa increased L^* for LM in the past vs. grain finishing (Scaglia et al. 2012; Duckett et al. 2013) with the latter authors citing several studies which report darker lean colour scores for forage vs. grain finished beef. For both muscles, chroma and hue angle values were greater ($P \leq 0.04$; contrast 1) in corn vs. forage finished beef which indicates a more true and vivid lean colour for grain finished beef.

In the past, a^* values often have not been affected when grain finished beef was compared with pasture (Scaglia et al. 2012; Duckett et al. 2013; Frueta et al. 2018) or silage finished beef (Faucitano et al. 2008). However, Frueta et al. (2018) found that after 9 d of simulated retail display, a^* values were greater in pasture vs. grain-fed beef, indicating a redder beef product. The effects of forage finishing on yellowness or b^* values have varied, with no differences between forage finished and grain-fed beef (French et al. 2000; Realini et al. 2004; Faucitano et al. 2008; Duckett et al. 2013) to pasture finishing having greater (Frueta et al. 2018) or lower (Scaglia et al. 2012) b^* values than grain-fed beef. Pordomingo et al. (2012*a*) found no differences in LM a^* or b^* values between cattle finished on alfalfa pasture or hay. In the present study, there was an MR × year interaction ($P = 0.03$) for ST chroma (data not presented) due to a much greater increase in chroma value from years 1 to 2 in ST from silage- vs. hay-fed cattle. Although hue angle was greater ($P = 0.01$; contrast 2; Table 4) in ST from pasture vs. conserved forage fed cattle, in general, there were few differences in colour attributes across methods of forage finishing.

Drip loss was not affected ($P \geq 0.52$) by MR for LM and ST muscles (Table 4), a finding which is in agreement with past studies (French et al. 2000; Faucitano et al. 2008) evaluating LM. Corn finishing increased ($P < 0.01$; contrast 1) IMF content in both muscles vs. forage finishing. This finding is consistent with the idea that much greater amounts of available energy in high grain diets results in increased IMF deposition vs. forage finished cattle (Faucitano et al. 2008; Scaglia et al. 2012; Duckett et al. 2013). In contrast, French et al. (2000) found no differences in IMF deposition between silage and grain finished cattle, whereas Pordomingo et al. (2012*b*) found that cattle finished on alfalfa hay had less IMF than pastured cattle which deposited similar amounts of IMF as cattle fed diets containing 40% and 70% alfalfa hay. The IMF content was not affected by forage finishing in the present study for both LM and ST. Although Girard et al. (2007) found that implanted, grain-fed cattle had greater plasma concentrations of vitamin B_{12} than cattle fed grass silage, vitamin B_{12} content in both muscles was not affected ($P \geq 0.33$) by MR in the present study. Forage finishing increased ($P \leq 0.02$; contrast 1) TBARS vs. corn-fed beef, whereas TBARS were similar between methods of forage finishing. These findings contrast to Realini et al. (2004) and Frueta et al. (2018) where lipid oxidation was lower in pasture vs. grain finished beef due to greater amounts of α tocopherol in the all forage diets. Management regimen × year interactions ($P < 0.05$) were present for IMF (LM), vitamin B_{12} (LM, ST), and TBARS (LM, ST). However, these data are not being presented as the data are best explained by examining the main effect of MR.

Although there was a trend ($P = 0.08$; contrast 1) for WBSF values for LM to be lower for grain vs. forage finished cattle, WBSF values were not affected by method of forage finishing for either muscle (Table 4). Duckett et al. (2013) found no differences in WBSF values between 14 and 28 d aged LM steaks from pasture and grain finished cattle. The latter authors also noted numerous studies where there were no differences in beef tenderness between forage finished and grain finished cattle marketed after a similar time on feed. However, this would not be the case for cattle marketed on a body composition endpoint. Duckett et al. (2013) noted that forage finished cattle are slaughtered after a longer time on feed than grain finished cattle resulting in lower tenderness scores (greater WBSF values) for forage vs. grain finished cattle. In the present study, there were no differences in time on feed across MR and no differences in WBSF values across methods of forage finishing for both LM and ST muscles. There was a trend for lower ($P = 0.07$; contrast 1) cooking losses for LT in corn-fed vs. forage finished beef, but otherwise there were no effects of MR on cooking losses for either muscle. As LT and ST steaks were aged from 7 to 21 d PM, WBSF and cooking loss values decreased ($P < 0.01$; data not presented) with no MR × PM ageing interactions.

Sensory evaluation

The trained taste panel scored LM steaks from corn-fed cattle with greater ($P \leq 0.01$; contrast 1) ratings for texture traits (softness, tenderness, and chewiness) vs. forage finished cattle (Table 5), a finding which is supported by the trend for lower WBSF values for LM from corn finished cattle (Table 4). As previously mentioned, Duckett et al. (2013) noted that many studies in the past have not found texture differences between forage and

Table 5. Effect of method of forage finishing on taste panel traits as compared with corn finished cattle.

	MR[a]					*P* for ANOVA[b]			*P* for contrasts[c]		
		Method of finishing on alfalfa							1	2	3
Item	Corn finished	Pasture	Hay	Silage	SEM	MR	Year	MR × year interaction	Corn vs. forage	Pasture vs. hay and silage	Hay vs. silage
Softness	6.97	6.43	6.28	6.66	0.23	0.009	0.11	0.27	0.003	0.85	0.06
Tenderness	6.91	6.34	6.15	6.58	0.22	0.010	0.003	0.35	0.004	0.90	0.05
Initial juiciness	6.38	5.97	5.73	6.32	0.28	0.006	0.59	0.46	0.029	0.78	0.003
Beef flavour	6.58	6.37	6.23	6.19	0.25	0.007	0.12	0.32	0.002	0.12	0.72
Grassy flavour	1.23	1.51	1.17	1.16	0.15	0.008	0.04	0.12	0.63	<0.001	0.95
Off flavor	0.99	1.06	0.92	0.97	0.14	0.61	0.004	0.02	0.99	0.21	0.59
Chewiness	6.32	5.72	5.45	5.95	0.27	0.002	<0.001	0.08	0.001	0.94	0.02
Juiciness	6.04	5.62	5.48	5.99	0.29	0.01	0.63	0.17	0.07	0.48	0.008
Flavour desirability	6.58	6.05	6.32	6.36	0.19	0.01	0.17	0.23	0.009	0.04	0.78
Overall acceptability	6.41	5.78	5.88	6.04	0.19	0.002	0.08	0.18	0.004	0.23	0.35

Note: MR, management regimen; ANOVA, analysis of variance; SEM, standard error of the mean. Taste panel traits evaluated using a 10 cm unstructured line scale included the following: 0 = very firm to 10 = very soft for softness; 0 = extremely tough to 10 = very tender for tenderness; 0 = very little juiciness to 10 = very high juiciness for initial juiciness; 0 = very weak beef flavor detected to 10 = very intense beef flavor detected for beef flavor; 0 = very weak grassy flavor detected to 10 = very intense grassy flavor detected for grassy flavor; 0 = very weak off flavor detected to 10 = very intense off flavor detected for off flavor; 0 = very chewy to 10 = not chewy for chewiness; 0 = very little juiciness to 10 = very high juiciness for overall juiciness; 0 = extremely undesirable flavour to 10 being extremely desirable flavour for flavour desirability; 0 = extremely unacceptable to 10 = extremely acceptable for oververall acceptability.

[a]Management regimen includes cattle finished on high grain corn diet (corn) or forage finished using alfalfa pasture (pasture), alfalfa hay (hay) or alfalfa silage (silage).

[b]ANOVA examines MR, year, and the MR × year interaction (MR × year).

[c]Contrasts: 1 = corn vs. forage finished cattle; 2 = pasture vs. the average of hay and silage finished cattle; 3 = hay vs. silage finished cattle.

grain finished beef when cattle are marketed after a similar time on feed, which is the case in the present study. However, Sitz et al. (2005) found that a trained taste panel found grain-fed beef to be superior in tenderness and juiciness to Australian grass-fed beef even when the grass-fed strip loin steaks were paired in the taste panel evaluation to American grain-fed strip loin steaks on the basis of similar WBSF values. Although there were no differences in texture ratings between pasture vs. conserved forage fed cattle ($P > 0.84$; contrast 2), all three texture ratings (softness, tenderness, and chewiness) were greater ($P \leq 0.06$; contrast 2) for silage vs. hay fed cattle. These taste panel findings contrast with the absence of method of forage finishing differences on WBSF (Table 4) and the work of Pordomingo et al. (2012*a*), where there were no differences in LM tenderness or connective tissue ratings between pasture and alfalfa hay fed steers. The present findings may not be reassuring to grass-fed beef producers for guaranteeing a tender product when they need to switch forage source due to limited forage supply from lack of precipitation for pasture production or seasonal changes in forage source.

Initial juiciness, beef flavour, and flavour desirability ratings were also greater ($P < 0.03$; contrast 1) for corn vs. forage finished beef (Table 5). Generally, juiciness ratings have not differed between forage finished and grain-fed beef (Garmyn et al. 2010; Scaglia et al. 2012; Duckett et al. 2013), although Duckett et al. (2013) reported lower juiciness for LM from cattle finished on pasture including alfalfa vs. a high-concentrate diet. Although Mandell et al. (1998) found no differences in juiciness ratings for alfalfa silage fed vs. grain-fed beef, there were also no diet differences in texture ratings (softness, tenderness, and time spent chewing). This contrasts against the present study where the taste panel provided lower ratings for both tenderness and juiciness attributes for forage vs. grain finished beef. That said, Sitz et al. (2005) reported lower juiciness ratings for Australian grass-fed strip loins (containing 6.1% IMF) when compared with American strip loins (containing 8.6% IMF) from grain-fed cattle, with IMF values much greater than the values found in the present study. Differences in IMF content for LM between forage and grain finished beef (Table 5) along with MR differences in tenderness may be responsible for juiciness differences. Similar to texture trait data, both initial and overall juiciness ratings were greater ($P < 0.01$; contrast 3) for silage vs. hay fed cattle (Table 5). Pordomingo et al. (2012*a*) found LM from cattle fed a 100% alfalfa hay diet to be less juicy than LM from cattle finished on alfalfa pasture; there were no differences in juiciness ratings in that study for LM between pasture finished cattle and cattle fed 40% or 70% hay diets.

Although lower flavour ratings for forage finished vs. grain-fed beef in the present study are supported by Cox et al. (2006) and Duckett et al. (2013), Pordomingo et al. (2012*a*) reported no differences in beef flavour for LM from cattle finished on 40%, 70%, or 100% alfalfa hay diets or alfalfa pasture. In contrast, Oltjen et al. (1971) reported higher flavour and tenderness ratings for LM from cattle fed a 100% alfalfa hay diet vs. a high-concentrate diet. More recently, Frank et al. (2016) maintain there will be few differences in beef flavour between forage and grain finished beef if similar IMF concentrations are present, which will be influenced by cattle breed and propensity for IMF deposition. The drastic differences in IMF content between grain and forage finished beef (Table 4) are most likely responsible for the lower flavor ratings for forage vs. grain-fed beef in the present study. The ability of consumers to detect these differences will also be affected by availability of product with varying IMF content, and previous consumer experience and preferences. Although there were no method of forage finishing differences on beef flavour, flavour desireability was lower ($P = 0.04$; contrast 2) in pasture finished beef vs. beef from cattle fed conserved forages. This is most likely attributed to greater ($P < 0.001$; contrast 2) but undesirable ratings for grassy flavour between pasture finished beef and beef from cattle fed conserved forages. Off flavours have been detected in the past with forage finishing using alfalfa silage (Mandell et al. 1997, 1998) or pasture (Duckett et al. 2013) when compared with grain finished beef. There was an MR × year interaction ($P < 0.03$; data not presented) in which off flavour scores ranged from 1.38 (hay finished) to 1.80 (corn finished) in year 1 and from 0.47 (hay finished) to 0.79 (corn finished) in year 2, with the largest drop in off flavour score occurring with corn finished beef across the 2 yr of the study. Because texture, juiciness, and flavour ratings were greater for corn-fed vs. forage finished beef, it is not surprising that the taste panel ranked corn-fed beef with greater ($P < 0.01$; contrast 1) ratings for overall acceptability, in agreement with Sitz et al. (2005) and Cox et al. (2006). The present study is unique due to the presence of method of forage finishing differences for palatability attributes, such that consumer eating experience may be influenced by the specific method of production for grass-fed beef, even though there may be limited differences in growth performance and carcass traits amongst methods of forage finishing.

Fatty acid composition

Fatty acid composition of dietary feedstuffs is presented in Table 1. The corn-based TMR contained greater amounts of oleic (C18:1) and linoleic (C18:2) acids than forages used in forage finishing, whereas the forages contained greater amounts of palmitic (C16:0) and α linolenic (C18:3*n*3) than the corn-based TMR. There were only small amounts of myristic

(C14:0), palmitoleic (C16:1), and stearic (C18:0) across all feedstuffs.

Fatty acid composition data for LT and ST are presented in Tables 6 and 7, respectively. Although MR × year interactions were present for specific fatty acids, only MR effects will be presented and discussed. Because Garcia et al. (2015) found that cultivar and cutting date affected fatty acid composition in alfalfa, it is not surprising there would be year effects and MR × year interactions for fatty acid composition. In addition, as we examined all fatty acid composition data, many of these differences in fatty acids are small and of questionable biological significance as stated in work examining the fatty acid composition in beef from cattle fed forage silages (Berthiaume et al. 2015). Qualitative fatty acid composition data for ST from grass-fed beef are not commonly found in the scientific literature, but data from the present study are generally similar to ST data from Pavan and Duckett (2013) for grass-fed beef from cattle finished on tall fescue pasture.

Corn-fed beef contained greater ($P \leq 0.09$; contrast 1) amounts of C14:0, C16:0, C16:1, C17:0, and oleic acid (C18:1) in both LM and ST in comparison to forage finished cattle (Tables 6 and 7). Although past studies (Mandell et al. 1998; Duckett et al. 2013) have also found that feeding a high-concentrate diet increased concentrations of C14:0 and oleic acid (C18:1) in LM relative to forage finishing, Pordomingo et al. (2012*b*) found that concentrations of these fatty acids in LM were similar when cattle were forage finished or fed with up to 60% concentrates in the diet. Palmitic (C16:0), C16:1, and C17:0 concentrations in LM were generally not affected by pasture finishing (Duckett et al. 2013) or method of forage finishing (Pordomingo et al. 2012*b*), although Duckett et al. (2013) reported a tendency for C16:1 concentrations to increase with finishing cattle on concentrates. Finishing cattle using alfalfa silage decreased C16:1 concentrations in LM without affecting C16:0 concentrations vs. grain-fed beef (Mandell et al. 1998). In the present study, forage finishing increased ($P < 0.01$; contrast 1) C18:0 concentrations in LT and ST muscles vs. grain finished beef but with no effects of method of forage finishing. These findings are supported by Duckett et al. (2013) evaluating diet effects on LM fatty acid composition, but in contrast to past studies evaluating forage finishing using alfalfa pasture or alfalfa hay (Pordomingo et al. 2012*b*) or alfalfa silage (Mandell et al. 1998) versus feeding concentrates.

Trans vaccenic acid concentrations were not affected ($P > 0.12$; contrast 1) by grain finishing in LM and ST which contrasts to Duckett et al. (2013) where grain finishing decreased concentrations of this fatty acid in LM. However, trans vaccenic acid concentrations were greater ($P < 0.001$; contrast 2) in LM from pastured vs. conserved forage fed cattle. Linoleic acid (C18:2) concentrations in LM were not affected by forage finishing in agreement with past studies (Mandell et al. 1998; Pordomingo et al. 2012*b*; Duckett et al. 2013). Forage finishing increased ($P = 0.04$; contrast 1) C18:2 concentrations vs. corn-fed beef for ST, whereas pastured cattle contained greater ($P < 0.01$; contrast 2) concentrations of C18:2 in ST than cattle feed conserved forages. Hay feeding increased ($P \leq 0.03$; contrast 3) the amount of C18:2 in both LM and ST vs. silage feeding. Omega-3 fatty acid concentrations (C18:3*n*3, C20:5, C22:5, and C22:6) were greater ($P < 0.01$; contrast 1) in forage vs. corn finished beef for LT and ST in agreement with Duckett et al. (2013), with limited effects in the present study for method of forage finishing. Pordomingo et al. (2012*b*) found that LM concentrations of C18:3*n*3, C20:5, C22:6, and CLA cis 9 trans 11 tended to be similar when hay diets were fed regardless of the amount of concentrates in the diet with amounts generally lower than for cattle finished on alfalfa pasture. Finishing cattle using alfalfa silage increased C18:3*n*3 (linolenic acid) concentrations in LM vs. grain-fed beef (Mandell et al. 1998). Duckett et al. (2013) also found that concentrations of CLA cis 9 trans 11 increased with pasture finishing, which was not the case in the present study. Forage finished beef contained more ($P < 0.01$; contrast 1) CLA trans 10 cis 12 than corn-fed beef for LM.

Method of forage finishing did not affect saturated fatty acid (SFA) levels in LT, which is in agreement with Pordomingo et al. (2012*b*), but did affect SFA levels in ST with greater ($P = 0.02$; contrast 2) amounts in beef from cattle fed conserved forages due to greater ($P = 0.03$; contrast 3) amounts in ST from cattle fed silage vs. hay. The greater amounts of oleic acid in corn-fed beef is a major contributor to the greater ($P < 0.01$; contrast 1) amounts of monounsaturated fatty acids concentrations and lower ($P \leq 0.04$; contrast 1) amounts of PUFA in corn vs. forage finished beef for both LM and ST in agreement with Duckett et al. (2013). The greater amounts of alpha linolenic, eicosapentaenoic, and docosahexaenoic acids in forage finished beef are responsible for greater ($P \leq 0.06$; contrast 1) concentrations of omega-3 (*n*-3) fatty acids and PUFA:SFA ratio for LM and ST. In contrast, the *n*-6:*n*-3 fatty acid ratio was greater ($P < 0.001$; contrast 1) in corn vs. forage finished beef for LM and ST in agreement with Duckett et al. (2013) and Pordomingo et al. (2012*b*). The latter authors found that the *n*-6:*n*-3 fatty acid ratio was lower in pasture vs. hay finished cattle which was not found in the present study. The biological significance of the limited differences in fatty acid concentrations for forage finished beef is of questionable biological significance. The fatty acid composition of forage finished beef in the present study is similar regardless of method of forage finishing, and it is superior to corn-fed beef for *n*-3 and PUFA as well as specific CLA isomers.

Table 6. Effect of method of forage finishing on fatty acid composition (g 100 g^{-1} of total fatty acids) in *longissimus thoracis* muscle as compared with corn finished cattle.

	MR					*P* for ANOVA			*P* for contrasts		
		Method of finishing on alfalfa							1	2	3
Item	Corn finished	Pasture	Hay	Silage	SEM	MR	Year	MR × year interaction	Corn vs. forage	Pasture vs. hay and silage	Hay vs. silage
Myristic C14:0	3.05	2.54	2.54	2.69	0.07	<0.001	0.09	0.21	<0.001	0.29	0.06
Palmitic C16:0	27.9	25.9	26.7	27.2	0.75	0.31	0.13	0.32	0.008	0.36	0.18
Palmitoleic C16:1	2.90	2.63	2.59	2.74	0.18	0.07	0.43	0.04	0.02	0.75	0.25
Heptadecanoic C17:0	0.86	1.01	1.16	1.14	0.04	0.11	0.04	0.008	<0.001	0.12	0.49
Stearic C18:0	15.6	18.0	17.8	17.9	0.44	<0.001	0.16	0.09	<0.001	0.78	0.70
Trans vaccenic C18:1	3.26	3.76	2.52	2.81	0.21	<0.001	0.31	0.01	0.30	<0.001	0.30
Oleic *cis* 9 C18:1	36.9	32.6	33.8	33.4	1.17	0.02	0.20	0.38	<0.005	0.44	0.57
Vaccenic *cis* 11 C18:1	1.41	1.49	1.59	1.46	0.17	0.51	0.64	0.56	0.25	0.85	0.13
Linoleic C18:2	4.35	5.07	4.81	4.14	0.72	0.45	0.89	0.02	0.35	0.51	0.03
Υ-Linolenic C18:3*n*-6	0.08	0.12	0.12	0.12	0.008	0.11	0.002	<0.001	0.003	0.99	0.63
α-Linolenic C18:3*n*-3	0.38	1.66	1.33	1.29	0.14	0.08	0.16	0.12	0.002	0.27	0.62
Eicosadienoic C20:2	0.08	0.11	0.12	0.12	0.02	0.008	0.005	<0.001	0.002	0.50	0.54
Eicosatrienoic C20:3	0.37	0.51	0.50	0.43	0.07	0.29	0.48	0.01	0.02	0.65	0.05
Arachidonic C20:4	1.56	1.63	1.73	1.88	0.49	0.60	0.09	0.008	0.49	0.81	0.44
Eicosapentaenoic C20:5	0.20	0.56	0.50	0.51	0.10	0.14	0.28	0.02	0.006	0.72	0.90
Docosatetraenoic C22:4	0.20	0.18	0.20	0.19	0.02	0.66	0.42	0.14	0.45	0.44	0.49
Docosapentaenoic C22:5	0.54	1.15	1.11	1.10	0.17	0.14	0.51	0.03	0.002	0.75	0.88
Docosahexaenoic C22:6	0.07	0.13	0.11	0.14	0.03	0.19	0.36	0.06	0.003	0.74	0.02
CLA cis 9 trans 11	0.49	0.54	0.42	0.44	0.05	<0.001	<0.001	0.002	0.29	<0.001	0.55
CLA trans 10 cis 12	0.06	0.08	0.08	0.09	0.02	0.009	0.08	0.05	0.008	0.68	0.86
SFA[a]	47.5	47.6	48.3	49.1	0.73	0.38	0.58	0.27	0.15	0.41	0.11
MUFA[b]	44.4	40.5	40.6	40.4	1.04	0.03	0.20	0.04	0.003	0.98	0.84
PUFA[c]	8.44	11.75	11.06	10.47	1.70	0.27	0.34	0.04	0.04	0.66	0.34
n-6 fatty acids[d]	6.66	7.56	7.51	6.88	1.34	0.59	0.28	0.01	0.33	0.82	0.22
n-3 fatty acids[e]	1.97	4.38	3.77	3.79	0.48	0.12	0.52	0.28	0.002	0.43	0.94
n-6:*n*-3 ratio	3.53	1.71	1.94	1.83	0.17	<0.001	<0.001	<0.001	<0.001	0.26	0.26
PUFA:SFA ratio	0.18	0.25	0.23	0.22	0.04	0.31	0.37	0.04	0.06	0.63	0.23

Note: MR, management regimen; ANOVA, analysis of variance; SEM, standard error of the mean; CLA, conjugated linoleic acid; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids. Management regimen includes cattle finished on high grain corn diet (corn) or forage finished using alfalfa pasture (pasture), alfalfa hay (hay) or alfalfa silage (silage). ANOVA examines MR, year, and the MR × year interaction (MR × year). Contrasts: 1 = corn vs. forage finished cattle; 2 = pasture vs. the average of hay and silage finished cattle; 3 = hay vs. silage finished cattle.

[a]SFA (Σ C14:0, C16:0, C17:0, and C18:0).

[b]MUFA (Σ C16:1, C18:1 cis 9, C18:1 cis 11, and C18:1 trans 11).

[c]PUFA (Σ C18:2*n*-6, C18:3*n*-6, C18:3*n*-3, C18:2cis 9 trans 11, C18:2 trans 10 cis 12, C20:2*n*-6, C20:3*n*-6, C20:4*n*-6, C20:5*n*-3, C22:4*n*-6, C22:5*n*-3, and C22:6*n*-3).

[d]*n*-6 fatty acids (Σ C18:2*n*-6, C18:3*n*-6, C20:2*n*-6, C20:3*n*-6, C20:4*n*-6, and C22:4*n*-6).

[e]*n*-3 fatty acids (ΣC18:3*n*-3, C20:5*n*-3, C22:5*n*-3, and C22:6*n*-3).

Table 7. Effects of method of forage finishing on fatty acid composition (g 100 g^{-1} of total fatty acids) in semitendinosus muscle as compared with corn finished cattle.

	MR								*P* for contrasts		
		Method of finishing on alfalfa				*P* for ANOVA			1	2	3
Item	Corn finished	Pasture	Hay	Silage	SEM	MR	Year	MR × year interaction	Corn vs. forage	Pasture vs. hay and silage	Hay vs. silage
Myristic C14:0	2.77	2.46	2.44	2.63	0.13	0.27	0.30	0.72	0.002	0.49	0.03
Palmitic C16:0	26.7	24.9	25.5	26.0	0.47	0.12	0.61	0.16	0.004	0.32	0.16
Palmitoleic C16:1	3.89	3.03	3.02	3.43	0.56	0.48	0.51	0.63	0.09	0.83	0.25
Heptadecanoic C17:0	0.82	0.97	1.11	1.09	0.02	<0.001	<0.001	0.01	<0.001	<0.001	0.475
Stearic C18:0	13.2	15.1	15.0	15.2	0.49	0.001	0.49	0.02	<0.001	0.97	0.49
Trans vaccenic C18:1	3.09	3.34	2.17	2.54	0.48	0.02	0.003	0.762	0.129	0.104	0.224
Oleic *cis* 9 C18:1	37.4	33.2	34.7	34.4	1.01	0.02	0.27	0.28	0.005	0.35	0.62
Vaccenic *cis* 11 C18:1	1.74	1.56	1.63	1.57	0.10	0.26	0.68	0.83	0.06	0.66	0.59
Linoleic C18:2	5.03	6.00	5.69	4.81	0.29	<0.001	0.76	0.23	0.04	0.004	0.002
γ-Linolenic C18:3*n*-6	0.09	0.13	0.14	0.13	0.007	0.11	<0.001	<0.001	0.001	0.71	0.17
α-Linolenic C18:3*n*-3	0.38	1.93	1.49	1.46	0.08	0.07	0.15	0.15	<0.001	0.11	0.76
Eicosadienoic C20:2	0.11	0.14	0.16	0.15	0.02	0.01	0.004	0.004	0.002	0.43	0.25
Eicosatrienoic C20:3	0.50	0.72	0.73	0.62	0.05	0.004	0.64	0.28	<0.001	0.51	0.01
Arachidonic C20:4	2.04	2.39	2.33	2.39	0.26	0.37	0.22	0.02	0.08	0.89	0.81
Eicosapentaenoic C20:5	0.32	0.86	0.82	0.78	0.06	<0.001	0.32	0.54	<0.001	0.25	0.55
Docosatetraenoic C22:4	0.27	0.25	0.27	0.25	0.03	0.61	0.84	0.97	0.57	0.77	0.20
Docosapentaenoic C22:5	0.83	1.72	1.67	1.56	0.09	<0.001	0.98	0.39	<0.001	0.21	0.28
Docosahexaenoic C22:6	0.12	0.20	0.16	0.19	0.01	0.17	0.85	0.65	<0.001	0.25	0.07
CLA cis 9 trans 11	0.51	0.58	0.45	0.51	0.11	0.71	<0.001	0.006	0.94	0.58	0.36
CLA trans 10 cis 12	0.09	0.10	0.09	0.09	0.02	0.37	0.09	0.89	0.69	0.09	0.57
SFA[a]	43.5	43.5	44.0	45.0	0.47	0.003	0.69	0.09	0.08	0.02	0.03
MUFA[b]	46.0	41.2	41.6	41.8	0.84	0.002	0.14	0.08	<0.001	0.58	0.74
PUFA[c]	10.2	15.0	14.0	12.9	0.75	0.17	0.39	0.49	<0.001	0.24	0.15
n-6 fatty acids[d]	8.0	9.6	9.4	8.3	0.56	0.19	0.31	0.15	0.03	0.34	0.07
n-3 fatty acids[e]	2.42	5.75	5.00	4.88	0.23	<0.001	0.27	0.67	<0.001	0.001	0.64
n-6:*n*-3 ratio	3.35	1.67	1.92	1.72	0.07	<0.001	0.005	<0.001	<0.001	0.01	0.003
PUFA:SFA ratio	0.24	0.35	0.32	0.29	0.02	<0.001	0.37	0.55	<0.001	0.005	0.06

Note: MR, management regimen; ANOVA, analysis of variance; SEM, standard error of the mean; CLA, conjugated linoleic acid; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids. Management regimen includes cattle finished on high grain corn diet (corn) or forage finished using alfalfa pasture (pasture), alfalfa hay (hay) or alfalfa silage (silage). ANOVA examines MR, year, and the MR × year interaction (MR × year). Contrasts: 1 = corn vs. forage finished cattle; 2 = pasture vs. the average of hay and silage finished cattle; 3 = hay vs. silage finished cattle.

[a]SFA (Σ C14:0, C16:0, C17:0, and C18:0).

[b]MUFA(Σ C16:1, C18:1 *cis*9, C18:1 cis 11, and C18:1 trans 11).

[c]PUFA (Σ C18:2*n*-6, C18:3*n*-6, C18:3*n*-3, C18:2 cis 9 trans 11, C18:2 trans 10 cis12, C20:2*n*-6, C20:3*n*-6, C20:4*n*-6, C20:5*n*-3, C22:4*n*-6, C22:5*n*-3, and C22:6*n*-3).

[d]*n*-6 fatty acids (Σ C18:2*n*-6, C18:3*n*-6, C20:2*n*-6, C20:3*n*-6, C20:4*n*-6, and C22:4*n*-6).

[e]*n*-3 fatty acids (ΣC18:3*n*-3, C20:5*n*-3, C22:5*n*-3, and C22:6*n*-3).

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Conclusions

Method of forage finishing generally did not affect most growth performance parameters, except when major differences in forage nutrient composition were present, which resulted in MR × year interactions. If producers want to use a forage finishing program, they need to be aware that forage quality will make a difference in performance and time on feed and whether forage finishing should be pursued based on the feed resources available to them. Low amounts of IMF deposition are a concern with forage finishing due to potential effects on beef juiciness and flavour versus grain finished beef. Method of forage finishing did affect specific palatability attributes, with beef from hay-fed cattle being less tender and juicy than beef from cattle finished on alfalfa pasture or alfalfa silage. This is a concern grass-fed beef producers may have when they need to switch forage source due to limited supply, lack of precipitation, or seasonal changes in forage source. More work is needed in this area to better understand the cause for reduced eating quality. Although forage finishing will increase the concentrations of *n*-3 PUFA in beef, these specific fatty acids are more prone to oxidation and the creation of off flavours. This may not be a concern for consumers who seek forage finished beef as they may prefer the differences in flavour vs. grain finished beef. In addition, these consumers are often seeking the more desirable fatty acid composition of forage finished beef as compared with the increased amounts of *n*-6 fatty acids found in grain finished beef.

The current study demonstrated that methods of forage finishing do not substantially affect the qualitative fatty acid composition of beef, which is important for beef producers who may want to forage finish on a year round basis and market grass-fed beef based on consumer perceptions about the health aspects from consuming grass vs. grain-fed beef. High-quality pasture will not be available at certain times of the year across Canada, meaning that conserved forages will have to be used for year round production of forage finished beef. Most consumers interpret "grass-fed" beef as beef being harvested from cattle managed on pasture. These consumers do not understand the concepts of pasture, silage, or hay, or that the forage fed to cattle can differ in botanical composition based on forage type (legumes vs. grasses), species, and quality (available energy, NDF, and protein). In addition, most consumers will not understand that production practices can vary with the use of implants, ionophores, and pharmaceuticals approved for beef production in Canada. The current study has demonstrated that the fatty acid composition of forage finished beef will generally be similar, regardless as to whether pasture, silage, or hay are used in the feeding program. This is important as the term "grass-fed" beef does not distinguish between the methods of forage finishing used in the production of grass-fed beef, nor will most beef producers go out of their way to state that the "grass-fed" beef was finished on hay or silage rather than pasture.

Acknowledgements

We thank the staff at the New Liskeard Agricultural Research Station and the University of Guelph Meat Laboratory. We sincerely appreciate the financial support provided by Beef Farmers of Ontario, the Beef Cattle Research Council, and the Ontario Ministry of Agriculture, Food and Rural Affairs/ University of Guelph Animal Production Systems Research Program.

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