Effects of calf- and yearling-fed beef production systems and growth promotants on production and profitability

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[1]*Agriculture and Agri-Food Canada, Lacombe Research Centre, 6000 C & E Trail, Lacombe, Alberta, Canada T4L 1W1;* [2]*Department of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, Alberta, Canada T6G 2P5; and* [3]*Alberta Agriculture and Rural Development, Lacombe Research Centre, 6000 C & E Trail, Lacombe, Alberta, Canada T4L 1W1.* *Received 26 March 2012, accepted 20 November 2012.*

López-Campos, Ó., Aalhus, J. L., Okine, E. K., Baron, V. S. and Basarab, J. A. 2013. **Effects of calf- and yearling-fed beef production systems and growth promotants on production and profitability**. Can. J. Anim. Sci. **93**: 171–184. In each of 2 yr, 112 spring-born steers were used to evaluate the effect of calf-fed vs. yearling-fed with and without growth implant and β-adrenergic agonist on production parameters and economic potential. Steers were grouped into: (1) non-implanted feeders harvested at 11–14 mo of age, (2) growth implanted feeders harvested at 11–14 mo of age, (3) non-implanted feeders harvested at 19–23 mo of age, and (4) growth implanted feeders harvested at 19–23 mo of age. Production data were collected and economic evaluation was performed. Calf-fed steers grew slower (1.21 vs. 1.99 ± 0.07 kg d^{-1}) and had a poorer feed conversion ratio [5.32 vs. 4.99 ± 0.34 kg dry matter intake (DMI) kg^{-1} gain] during the feedlot dietary adjustment period than yearling-fed. Calf-fed steers were more efficient than yearling-fed during the first 76–83 d (5.16 vs. 7.33 ± 0.11 kg DMI kg^{-1} gain) and latter 48–79 d (5.69 vs. 14.28 ± 1.50 kg DMI kg^{-1} gain) of the finishing period. Implanted steers were more efficient than non-implanted during the dietary feedlot adjustment period (4.80 vs. 5.52 ± 0.15 kg DMI kg^{-1} gain), and during the first 76–83 d (6.05 vs. 6.44 ± 0.11 kg DMI kg^{-1} gain) and latter 48–79 d of the finishing period (9.29 vs. 10.69 ± 1.50 kg DMI kg^{-1} gain). Implanted steers grew 11.4–19.6% faster than non-implanted throughout the finishing period, while yearling-fed grew 11.1–12.9% faster during the first 76–83 d, but 49.1–64.4% slower during the last 48–79 d of the finishing period compared with calf-fed. Quality grade was improved for non-implanted steers, with 43.6% of yearling-fed and 35.7% calf-fed steers grading AAA. Adjusted net return was best for calf-fed implanted ($17.52 head^{-1}), followed by calf-fed non-implanted ($ −41.92 head^{-1}), yearling-fed implanted ($ −73.77 head^{-1}), and yearling-fed non-implanted ($ −99.65 head^{-1}) production strategies. The results of the present study suggest that reducing age at slaughter combined with growth implant can increase profit and reduce risk, but growth implants can negatively affect the carcass quality.

Key words: Cattle, feed efficiency, net return, hormone implant, β-adrenergic agonist

López-Campos, Ó., Aalhus, J. L., Okine, E. K., Baron, V. S. et Basarab, J. A. 2013. **Incidence de l'élevage des veaux et des bouvillons d'un an et des accélérateurs de croissance sur la production et la rentabilité**. Can. J. Anim. Sci. **93**: 171–184. Chaque année pendant deux ans, les auteurs ont recouru à 112 veaux nés le même printemps pour comparer l'incidence de l'engraissement des veaux et de l'engraissement des bouvillons d'un an avec et sans implantation d'un promoteur de croissance et d'un agoniste β-adrénergique sur les paramètres de production et les possibilités de rendement. Les bouvillons ont été regroupés comme suit : (1) bovins d'engrais sans implant sacrifiés à l'âge de 11 à 14 mois; (2) bovins d'engrais avec implant abattus à l'âge de 11 à 14 mois; (3) bovins d'engrais sans implant sacrifiés à l'âge de 19 à 23 mois; (4) bovins d'engrais avec implant abattus à l'âge de 19 à 23 mois. Les données sur la production ont été recueillies, puis on a procédé à une évaluation économique. Les veaux d'engrais croissent plus lentement (1,21 c. $1,99 \pm 0,07$ kg jour^{-1}) et avaient un indice de consommation plus faible (5,32 c. $4,99 \pm 0,34$ kg de matière sèche ingérée par kg de gain) que les bouvillons d'engrais d'un an pendant la période d'ajustement au régime en parc d'engraissement. Les veaux d'engrais s'avèrent plus efficaces que les bouvillons d'engrais d'un an pendant les 76 à 83 premiers jours (5,16 c. $7,33 \pm 0,11$ kg de matière sèche ingérée par kg de gain) et les 48 à 79 derniers jours (5,69 c. $14,28 \pm 1,50$ kg de matière sèche ingérée par kg de gain) de la période de finition. Les bouvillons avec implant sont plus efficaces que ceux sans implant durant la période d'ajustement au régime dans l'enclos (4,80 c. $5,52 \pm 0,15$ kg de matière sèche ingérée par kg de gain) ainsi que pendant les 76 à 83 premiers jours (6,05 c. $6,44 \pm 0,11$ kg de matière sèche ingérée par kg de gain) et les 48 à 79 derniers jours de la période de finition (9,29 c. $10,69 \pm 1,50$ kg de matière sèche ingérée par kg de gain). Les bouvillons avec implant ont grossi 11,4 à 19,6 % plus vite que ceux sans implant durant la période de finition, tandis que les bouvillons d'un an ont crû 11,1 à 12,9 % plus vite

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Abbreviations: **ADG**, average daily gain; **DM**, dry matter; **DMI**, dry matter intake; **FCR**, feed conversion ratio; **TBA**, trenbolone acetate; **TDN**, total digestible nutrients

pendant les 76 à 83 premiers jours, mais 49,1 à 64,4 % plus lentement durant les 48 à 79 derniers jours de la période de finition, comparativement aux veaux sans implant. La qualité des carcasses était plus élevée pour les animaux sans implant, 43,6 % des bouvillons d'un an et 35,7 % des veaux atteignant la classe AAA. Après correction, ce sont les veaux d'engrais avec implant qui engendrent le meilleur revenu net (17,52 $ par tête). Viennent ensuite les veaux d'engrais sans implant (−41,92 $ par tête), les bouvillons d'engrais d'un an avec implant (−73,77 $ par tête) et les bouvillons d'engrais d'un an sans implant (−99,65 $ par tête). Les résultats de cette étude laissent croire que diminuer l'âge à l'abattage et utiliser un implant peuvent rehausser la rentabilité et réduire les risques. Le recours à un implant peut néanmoins avoir une incidence négative sur la qualité de la carcasse.

Mots clés: Bovins, valorisation des aliments, revenu net, implant hormonal, agoniste β-adrénergique

Increasing farm input cost, fluctuating beef prices, consumers' perceptions relating to animal health and food safety, export market access and climate change continue to create challenges for the beef cattle industry. To address these challenges numerous cattle management strategies have been developed to improve efficiency, reduce input cost and enable producers to access differentiated beef products to satisfy market needs. However, there is often a trade-off between beef carcass quality, production economics and environmental sustainability (Reinhardt 2007; McAllister et al. 2011). One strategy that may improve efficiency, profitability, environmental sustainability and carcass quality is to reduce the average age at harvest for youthful cattle. In North America post-weaned calves are either directed to an intensive, calf-fed or an extensive, yearling-fed beef cattle production system. Calf-fed production requires the earlier placement of weaned calves on high concentrate following a 1–2 mo dietary adjustment period. Calf-fed production systems are reported to have improved gain and efficiency, reduced feed intake, no effect on the consumption of total concentrate and reduced liver and reticulo-rumen weights compared with yearling-fed production systems where steers are grown on backgrounding diets for varying periods before finishing (Myers et al. 1999b). Profitability and risk tended to favor the calf-fed over the yearling-fed system (Winterholler et al. 2008a; Small et al. 2009). Despite these observations, backgrounding and grazing yearlings will continue to be profitable for many producers with forage resources as it lends flexibility and/or economic buffering capacity to a ranch.

Integrated into these two beef production systems is the use of growth implants and β-adrenergic agonists as a routine management practices. During the past two decades, newer anabolic compounds have been implemented and strategies for implanting feedlot cattle have been refined. Combinations of implants that contain estrogenic and androgenic hormones are a usual practice in the North American cattle industry that produces a greater response than single-hormone implant strategies (Reinhardt 2007). Hormonal growth promotants such as estradiol benzoate and trenbolone acetate (TBA) are well known to improve feed efficiency, weight gain and muscle growth (Apple et al. 1991; Foutz et al. 1997) in grazing and feedlot cattle resulting in substantial economic gains (Foutz et al. 1997; Duckett and Andrae 2001). However, growth implants have a negative effect on meat quality traits through decreased marbling scores and quality grade, and increased incidence of dark cutting (Foutz et al. 1997; Roeber et al. 2000; Reiling and Johnson 2003). β-adrenergic agonists work by redirecting nutrients away from fat deposition to protein synthesis, resulting in increased muscle fiber size and lean meat yield, and increased growth rate and feed conversion ratio (FCR) (Gruber et al. 2007; Winterholler et al. 2007). Ractopamine hydrochloride, a β-adrenergic agonist, fed at 200 mg d^{-1} during the last 28–42 d before slaughter has been shown to improve average daily gain and gain to feed ratio by 20%, final slaughter weight by 1.2–2.1%, carcass weight by 1.9–2.8% and dressing percentage by 0.5% (Schroeder et al. 2005a, b; Winterholler et al. 2007, 2008b), but had no effect on dry matter intake, yield grades and marbling score (Winterholler et al. 2007; Quinn et al. 2008).

Although published studies have addressed many individual aspects of calf-fed and yearling-fed beef production, insufficient research has been conducted to evaluate the interactions among biological type, growth implant and repartitioning agents on beef production, economics and carcass quality. Hormonal growth promotants and β-adrenergic agonists work through separate mechanisms; however, both act to increase protein deposition. Whether their effects are synergistic or additive is uncertain. Thus, the objectives were to determine the effect of reduced age at slaughter using calf-fed vs. yearling-fed production systems with and without aggressive growth implant and β-adrenergic agonist on production characteristics and economics.

MATERIALS AND METHODS

In this 2-yr study, the animals were maintained at the Lacombe Research Centre, Agriculture and Agri-Food Canada, Lacombe, Alberta. All dietary treatments and experimental procedures were approved by the Lacombe Research Centre Animal Care Committee and animals were cared for as outlined under the guidelines established by the Canadian Council on Animal Care (1993). The management of the cow-calf herd has previously been described by Basarab et al. (2007, 2011). Briefly, calves were born from the first week in March to mid-May of 2008 (year 1) and 2009 (year 2). Within 24 h of birth, calves were individually identified with a plastic visual tag, weighed, and male calves were castrated by the elastic banding method. Calves were vaccinated for infectious bovine rhinotracheitis, bovine parainfluenza-3, bovine viral diarrhea (Types I and II), bovine respiratory syncytial viruses, *haemophilus somnus*, *pasteurella multocida* and clostridial diseases and dehorned if necessary using hot dehorning irons at 1–2 mo of age. Calves then had their vaccinations boosted 6 wk before weaning and then again at weaning, along with pour-on parasitic control for maximum protection post weaning. At weaning, all calves were weighed and tagged with a half-duplex radio frequency transponder button (Allflex USA, Inc., Dallas/Fort Worth Airport, TX) in the right ear.

In each of the 2 yr, 112 crossbred steer calves were assigned at weaning to a $2 \times 2 \times 2$ factorial arrangement of treatments to determine the effect of production system (calf-fed harvested at 11–14 mo of age; yearling-fed harvested at 19–23 mo of age), growth implant (no implant; implant) and β-adrenergic agonist (no β-agonist; β-agonist) on performance, carcass quality and economics. Steer calves were allocated to production systems and implant groups based on breed cross (Angus-Hereford vs. Charolais–Red Angus calves), birth date, calf weight (42.2 kg, SD = 6.3 kg) and dam age (4.8 yr, SD = 2.7 yr) and then one-half ($n = 56$) of the calf-fed and yearling-fed steers were implanted with 200 mg progesterone and 20 mg estradiol benzoate (Component E-S, Elanco-Animal Health A Division of Eli Lilly Canada Inc., Toronto, ON). The 2008 and 2009 born Angus–Hereford calves were produced from Aberdeen Angus and Red Angus bulls and the Charolais–Red Angus calves were produced from Charolais and Red Angus sires in multi-sire mating groups. All bulls and their calves were genotype using a custom single nucleotide polymorphism parentage panel of 96 markers, and were genotyped on an Illumina's BeadXpress reader using the VeraCode for GoldenGate Genotyping protocol (Illumina 2012). The single nucleotide polymorphisms were from the USDA–Marc list of 121 parentage markers.

Calf-fed Production System

Calf-fed steers (268 kg, SD = 5.4 kg; 191 d, SD = 3) were placed into a feedlot pen fitted with eight GrowSafe® feeding stations (GrowSafe® System Inc., Airdrie, AB) where they were fed twice daily ad libitum and adjusted from a high-forage-based diet to a high-grain finishing diet over 27–42 d. The adjustment period was followed by an 80–86 d test period when the steers were fed twice daily ad libitum a finishing diet. The average ingredient composition of the diet [as dry matter (DM) basis] fed during the finishing phase was 81.4% rolled barley grain and protein supplement premix, 9.7% grass silage and 8.9% barley silage in the first year and 80.9% rolled barley grain and protein supplement premix and 20.0% barley silage in the second year (Table 1). Wood chips and shavings, used as bedding, were placed into the pen as required, and animals had free choice access to water. The GrowSafe® feeding stations and concrete apron were covered by an open-sided wooden roof that prevented precipitation from entering the feeding tubs. Steers were weighed on 2 consecutive days at the start and end of the feed intake test period, and at approximately 28-d intervals. Steers were also measured for ultrasound backfat thickness (mm), ribeye area (cm^2) and marbling score at the start and end of the test period using an Aloka 500V diagnostic real-time ultrasound with a 17-cm 3.5 MHz linear array transducer (Overseas Monitor Corporation Ltd., Richmond, BC) by a certified ultrasound technician using procedures described by Brethour (1992). Marbling score is a measure of intramuscular fat where trace marbling (300; USDA 1997) or less = 1.00 to 3.99 (Canada A quality grade), slight marbling (400; USDA, 1997) = 4.00 to 4.99 (Canada AA quality grade), small (500; USDA, 1997) to moderate (700; USDA, 1997) marbling = 5.00 to 7.99 (Canada AAA quality grade) and slightly abundant (800; USDA, 1997) or more marbling = 8.00 to 11.00 (Canada Prime).

In each year, half the calf-fed steers ($n = 28$) were implanted with 200 mg progesterone and 20 mg estradiol benzoate (Component E-S, Elanco-Animal Health A Division of Eli Lilly Canada Inc., Toronto, ON) at weaning, and re-implanted with 120 mg TBA and 24 mg estradiol (Component TE-S, Elanco-Animal Health A Division of Eli Lilly Canada Inc., Toronto, ON) approximately 90–100 d before slaughter. At the end of the feed intake test, steers were removed from the GrowSafe® pen and assigned to one of eight small feedlot pens based on implant group, breed cross and body weight such that there were two pens of heavier and two pens of lighter steers per implant group per year (seven steers per pen). Two pens ($n = 14$) of non-implanted and implanted steers were supplemented with 200 mg head^{-1} d^{-1} of ractopamine hydrochloride 28 d before slaughter (Optaflexx, Elanco-Animal Health A Division of Eli Lilly Canada Inc., Toronto, ON).

Yearling-fed Production System

Following weaning, 56 yearling-fed steers (266 kg, SD = 4.6 kg; 193 d, SD = 3) per year were placed on meadow-bromegrass (*Bromus riparius* Rehm.)–alfalfa (*Medicago sativa* L.) pasture where they were rotationally grazed until early December when the snow prevented grazing (52 d in 2008/2009; 31 d in 2009/2010). The average nutrient composition of the pasture is given in Table 2. Calves were supplemented with a protein lick until the end of fall grazing at which time they were weighed and sorted into eight small feedlot pens based on implant group, breed cross and body weight. This resulted in four pens per implant group per year and seven steers per pen. A backgrounding diet consisting (as DM basis) of 43.1% barley silage, 41.1%

Table 1. Average ingredient and nutrient composition of the finishing diet fed to calf-fed steers

Ingredient and nutrient composition	Year cycle 1 *n*	mean	SD	Year cycle 2 *n*	Mean	SD
Ingredient Composition (% as fed)[z]						
Barley grain protein mix[y]	211	8167.42	56.051	162	5880.0.74	68.1132
Grass silage	86	911.827	32.4382	0	0.00	0.00
Barley silage	125	208.769	41.4088	162	4120.260	62.9711
Nutrient composition (% DM)						
Dry matter (%)	11	65.53	6.26	11	64.547	3.65
Crude protein (%)	11	13.218	1.09	11	14.74	1.20
Acid detergent fiber (%)	11	15.219	3.68	11	16.24	3.26
Neutral detergent fiber (%)	11	27.655	4.45	11	27.218	5.07
Calcium (%)	11	0.659	0.19	11	0.869	0.27
Phosphorus (%)	11	0.394	0.09	11	0.394	0.03
Magnesium (%)	11	0.21	0.12	11	0.192	0.02
Potasium (%)	11	0.787	0.19	11	0.83	0.14
Total digestible nutrients[x] (%)	11	75.20	1.72	11	74.71	1.52
Metabolizable energy[x] (MJ kg^{-1} DM)	11	11.354	0.26	11	11.283	0.23

[z]The diet composition was recorded daily as the ingredients were weighed into the feed truck.
[y]This feed mixture was supplied by FeedRite Inc. (Lacombe, AB) and contained 89.2% dry matter and consisted of 88.4% rolled barley, 5.0% 32:14 beef supplement, 3.33% protein pellets, 1.65% vitamin E premix, 1.0% molasses, 0.5% vegetable oil, 0.1% mold zap, 0.01% tylan 40 and 0.01% fortified vitamin ADE premix (as fed basis). Its nutrient composition (DM basis) was formulated to contain 14.01% crude protein, 2.58% fat, 8.47% fiber, 4.53% ash, 0.60% calcium, 0.36% phosphorus, 0.34% salt, 0.14% sodium, 0.59% potassium, 0.16% magnesium, 0.19% sulfur, 71.2 mg kg^{-1} manganese, 76.9 mg kg^{-1} zinc, 85.0 mg kg^{-1} iron, 27.4 mg kg^{-1} copper, 0.52 mg kg^{-1} cobalt, 1.18 mg kg^{-1} iodine, 0.34 mg kg^{-1} added selenium, 6.72 KIU kg^{-1} added vitamin A, 0.95 KIU kg^{-1} added vitamin D, 36.32 IU kg^{-1} added vitamin E, 37.0 mg kg^{-1} monensin and 12.3 mg kg^{-1} tylosin.
[x]The following equations were used to calculate %TDN and ME: %TDN = 82.299 − (ADF, % × 0.467); ME, MJ/kg DM = ((%TDN/100) × 4.4 × 0.82) × 4.184 MJ Mcal^{-1}.

alfalfa meadow bromegrass hay and 15.8% 60:40 rolled barley:oat grain mix was fed for 192 d in 2008–2009. In 2009–2010 the diet consisted of 89.5% barley silage and 10.6% barley straw and was fed for 189 d (Table 2). The yearling-fed implanted steers (28 per year) were re-implanted with 200 mg progesterone and 20 mg estradiol benzoate 83 d after their first implant (second time) and again 71 d later (third time). In early June of each year and at the end of the feedlot backgrounding period, steers were weighed, measured for ultrasound backfat thickness, rib-eye area and marbling score and implanted a fourth time (86 d after implant 3) with 200 mg progesterone and 20 mg estradiol benzoate. Body weight and backfat were then used to sort treatments into two groups of implanted and non-implanted steers. These four groups of steers then grazed meadow brome alfalfa pastures (Table 2) until September when they were weighed, measured for ultrasound backfat, rib-eye area and marbling, and implanted a fifth time, 90–100 d before the slaughter, with 120 mg TBA and 24 mg estradiol. Yearling-fed steers were then placed into a feedlot pen fitted with eight GrowSafe® feeding stations (GrowSafe® System Inc., Airdrie, AB) where they were fed twice daily ad libitum and adjusted from a high-forage-based diet to a high-grain finishing diet over 21–23 d. The 3 wk adjustment period was followed by an 86 d test period where the steers were fed twice daily ad libitum a finishing diet. The average ingredient composition of the diet (as DM basis) during the finishing phase was 79.0% rolled barley grain and protein supplement premix, and 21.0% barley silage in the first year and 74.9% rolled barley grain and protein supplement premix, and 18.9% barley silage in the second year (Table 3). Yearling-fed steers followed the same procedure during the individual feed intake test period as described above for the calf-fed steers. At the end of the feed intake test, steers were removed from the GrowSafe® pen and assigned to one of eight small feedlot pens based on implant group, breed cross and body weight such that there were two pens of heavier and two pens of lighter steers per implant group per year (seven steers per pen). Two pens of non-implanted and implanted steers were supplemented with 200 mg head^{-1} d^{-1} of ractopamine hydrochloride 28 d before slaughter.

In both treatments, calf-fed and yearling-fed steers were targeted to be slaughtered at a constant backfat end point of 8–10 mm (based on ultrasound measurements) in four groups of 14 per year. At 1- to 2-wk intervals steers were trucked 3 km for processing, similar to commercial conditions, at the Lacombe Research Centre abattoir such that there were seven implanted and seven non-implanted steers within each slaughter group. Final live weight and hot carcass weight were obtained from all steers at the time of slaughter. Hot dressing percentage was calculated as the ratio of hot carcass weight to live weight (dressing percentage = hot carcass weight/slaughter weight × 100). The carcasses

Table 2. Ingredients and nutrients composition of the backgrounding diets fed to yearling-fed steers

	Year cycle 1			Year cycle 2		
Ingredient and nutrient composition	*n*	mean	SD	*n*	mean	SD
Fall pasture, alfalfa meadow bromegrass						
Nutrient composition, % DM						
Crude protein (%)	12	9.40	2.83	12	7.576	1.68
Acid detergent fiber (%)	12	36.82	4.54	12	38.549	2.27
Neutral detergent fiber (%)	12	55.64	3.86	12	60.21	2.56
Calcium (%)	6	0.667	0.13	6	0.56	0.03
Phosphorus (%)	6	0.263	0.03	6	0.172	0.02
Magnesium (%)	6	0.192	0.01	6	0.172	0.01
Potassium (%)	6	1.778	0.57	6	1.31	0.32
Total digestible nutrients[z] (%)	12	57.02	5.91	12	54.84	2.96
Metabolizable energy[z] (MJ kg^{-1} DM)	12	8.61	0.89	12	8.283	0.45
Feedlot period (189–192 d)						
Ingredient composition (% as fedDM)[y]						
Barley silage	192	643.103	117.365	18989	9589.325	6.5918
Barley straw	–	–	–	18989	410.686	614.5986
Alfalfa meadow bromegrass hay	192	2641.071	181.8162	–	–	–
60:40% rolled barley:oat grain mix	192	915.908	12.5548	–	–	–
Nutrient composition (% DM)						
Dry matter (%)	7	51.475	5.53	5	50.81	3.88
Crude protein (%)	7	12.60	1.52	5	9.83	0.54
Acid detergent fiber (%),	7	35.273	2.32	5	38.70	2.43
Neutral detergent fiber (%)	7	55.071	1.81	5	58.50	5.69
Calcium (%)	7	0.657	0.07	5	0.50	0.09
Phosphorus (%)	7	0.30	0.03	5	0.24	0.02
Magnesium (%)	7	0.20	0.02	5	0.182	0.02
Potassium (%)	7	1.657	0.37	5	1.576	0.16
Total digestible nutrients[z] (%)	7	59.04	1.08	5	54.576	3.17
Metabolizable energy[z] (MJ kg^{-1} DM)	7	8.91	0.16	5	8.24	0.48
Summer pasture, alfalfa meadow bromegrass						
Nutrient composition (% DM)						
Crude protein (%)	36	13.439	2.51	36	11.41	2.55
Acid detergent fiber (%)	36	34.374	2.71	36	35.80	2.34
Neutral detergent fiber (%)	36	56.667	2.68	36	59.01	1.81
Total digestible nutrients[z] (%)	36	60.21	3.53	36	58.354	3.04
Metabolizable energy[z] (MJ kg^{-1} DM)	36	9.091	0.53	36	8.81	0.46

[z]The following equations were used to calculate %TDN and ME: Grain-based: Forage-based: %TDN = 104.96 − (ADF, % − 1.302); ME, MJ kg^{-1} DM = ((%TDN/100) × 4.4 × 0.82) × 4.184 MJ $Mcal^{-1}$.
[y]The diet composition was recorded daily as the ingredients were weighed into the feed truck.

were then chilled at 2°C overnight for 24-h, knife-ribbed at the grade site between the 12th and 13th ribs, and assessed for fat thickness, rib-eye area, estimated lean yield (Canadian Food Inspection Agency 1992) and quality grade (American Meat Science Association 1990) by two certified graders.

Feed Analysis

Feed samples for the fall pasture were collected twice, initially when the cattle went onto pasture and then when the cattle came off pasture. Feed samples for the summer grazing period were collected twice per month, once early and once late, from each of three paddocks for June, July and August of each year. The finishing diet composition was recorded daily as the ingredients were weighed into the feed truck. Finishing feed samples of the total mixed ration for the steers were collected weekly, pooled monthly and analyzed for DM, calcium, phosphorus, crude protein, neutral detergent fiber and acid detergent fiber (ADF). The following equations were used to calculate percent total digestible nutrients (TDN) and meatbolizable energy (ME):

$$\%\mathrm{TDN} = 82.299 - (\mathrm{ADF}, \% \times 0.467);\ \mathrm{ME},\ \mathrm{MJ\ kg^{-1}\ DM} = ((\%\mathrm{TDN}/100) \times 4.4 \times 0.82) \times 4.184\ \mathrm{MJ\ Mcal^{-1}}.$$

Table 3. Ingredients and nutrients composition of the finishing diet fed to yearling-fed steers

	Year cycle 1			Year cycle 2		
Ingredient and nutrient composition	*n*	mean	SD	*n*	mean	SD
Ingredient composition (% as DM fed)[z]						
Barley grain protein mix[y]	152	6479.082	3.0976	146	6274.039	79.2446
Barley silage	152	3521.180	31.0985	146	3718.97	73.627
Nutrient composition (% DM)						
Dry matter (%)	7	66.897	2.67	5	70.678	1.77
Crude Protein (%)	7	12.586	0.49	5	13.61	0.37
Acid detergent fiber (%)	7	16.73	1.22	5	17.697	3.03
Neutral detergent fiber (%)	7	28.11	1.88	5	28.21	4.38
Calcium (%)	7	0.93	0.27	5	01.970	0.15
Phosphorus (%)	7	0.475	0.06	5	0.354	0.02
Magnesium (%)	7	0.192	0.01	5	0.20	0.01
Potassium (%)	7	0.768	0.04	5	1.017	0.09
Total digestible nutrients[x] (%)	7	74.495	0.57	5	74.04	1.41
Metabolizable energy[x] (MJ kg^{-1} DM)	7	11.24	0.09	5	11.182	0.21

[z]The diet composition was recorded daily as the ingredients were weighed into the feed truck.
[y]This feed mixture was supplied by FeedRite Inc. (Lacombe, AB) and contained 89.2% dry matter and consisted of 93.28% rolled barley, 4.5% 32:14 beef supplement, 1.10% vitamin E premix, 0.5% molasses, 0.5% vegetable oil, 0.1% mold zap, and 0.02% fortified vitamin ADE premix (as fed basis). Its nutrient composition (DM basis) was formulated to contain 12.64% crude protein, 2.61% fat, 8.61% fiber, 4.78% ash, 0.66% calcium, 0.45% phosphorus, 0.25% salt, 0.10% sodium, 0.53% potassium, 0.15% magnesium, 0.18% sulfur, 157.1 mg kg^{-1} manganese, 202.3 mg kg^{-1} zinc, 142.7 mg kg^{-1} iron, 64.5 mg kg^{-1} copper, 1.18 mg kg^{-1} cobalt, 3.10 mg kg^{-1} iodine, 0.91 mg kg^{-1} added selenium, 15.13 KIU kg^{-1} added vitamin A, 2.83 KIU kg^{-1} added vitamin D, 56.02 IU kg^{-1} added vitamin E, and 24.7 mg kg^{-1} monensin.
[x]The following equations were used to calculate %TDN and ME: %TDN = 82.299 − (ADF, % × 0.467); ME, MJ kg^{-1} DM = ((%TDN/100) × 4.4 × 0.82) × 4.184 MJ $Mcal^{-1}$.

Dry matter was determined by drying a sample of the diet at 100°C in a forced-air oven to a constant weight. The calcium, phosphorus and nitrogen contents of the samples were determined by Association of Official Analytical Chemists procedures (AOAC 1996). Crude protein was calculated as 6.25 × N. Neutral detergent fiber and acid detergent fiber contents of feed samples were determined by the procedure of Van Soest et al. (1991) (Table 1).

Calculations

Body weight and average daily gain (ADG) during the GrowSafe® feeding intake test period were calculated by a linear regression of the animal's observed body weight against day on-test (Basarab et al. 2003). Average daily feed intake of each animal over the test period was converted to total DMI based on the diet DM given in Table 1.

Economic Value

The net return for each steer was calculated as follows:

$$\mathrm{Cost_t} = \mathrm{Cost_a} + \mathrm{Cost_i} + \mathrm{Cost_f} + \mathrm{Cost_y} + \mathrm{Cost_{int}} + \mathrm{Cost_d} + \mathrm{Cost_m} + \mathrm{Cost_g};$$

$$\text{Net return}_{\text{live}} = \text{Income} - \mathrm{Cost_t};$$

$$\text{Net return}_{\text{rail}} = \text{Income} + \text{Premium}_q - \text{discount}_y - \text{discount}_w$$

where the Income was determined by multiplying carcass weight by a 5-yr (2006–2010) monthly average rail price for fed cattle slaughtered in Alberta, and then by each year's monthly average rail price to obtain six estimates of net return. These prices were obtained from the *Weekly Livestock Market Review* (Alberta Agriculture and Rural Development) and were determined as the average low and high price for the month to obtain within year monthly averages, and then these average monthly prices were averaged over 5-yr (2006–2010) for each month. Monthly average rail price over this 5-yr period were \$3.1668, \$3.1632, \$3.3169, \$3.4342, \$3.3526, \$3.2078, \$3.2098, \$3.2245, \$3.1924, \$3.1574, \$3.1767 and \$3.1840 kg^{-1} for January through December, respectively. Additional quality grade premiums (Premium_q), yield grade discounts (discount_y) and carcass weight discounts (discount_w) were obtained from Canfax (Calgary, AB). Quality grade AAA, AA and A received premiums of \$0.2646, \$0.0661 and \$0.0000 kg^{-1} carcass weight, respectively, while yield grade Y1, Y2 and Y3 received discounts of \$0.0000, \$ −0.0661 and −0.2205 kg^{-1} carcass weight, respectively. Carcasses that weighed < 249.5 kg, 249.5 kg to < 430.9 kg, 430.9 kg to < 453.6 kg and = 453.6 kg received discounts of \$ −0.3307, \$0.00, \$ ≥ 0.1653 and \$ −0.3307 kg^{-1} carcass weight, respectively. $\mathrm{Cost_a}$ equals animal cost to the feedlot or pasture and was calculated by multiplying steer live weight by buying price at the beginning of the trial plus \$10.15 $head^{-1}$ 1 for marketing and transportation. Buying price was based on feeder prices for central Alberta (Ponoka) for the week ending 2008 Oct. 17 and 2008 Oct. 23 (Alberta Agriculture and Rural Development 2008–2009).

Missing prices for a weight class were estimated using a price-weight slide for the week in which the feeders were purchased. $Cost_i$ equals induction costs for processing, vaccination, medicines and veterinary services and was 3% of feeder cost (Canfax Trends, Calgary, AB). $Cost_f$ equals feed cost and were based on the as-fed price for barley grain protein premix ($0.236 kg^{-1}), barley or oat grain ($0.232 kg^{-1}), barley silage ($0.027 kg^{-1}), hay silage ($0.045 kg^{-1}), meadow brome alfalfa hay ($0.060 kg^{-1}) and summer or fall pasture ($22 per animal unit month). $Cost_y$ equals total feedlot yardage or overhead costs and is calculated by multiplying days on feed in the feedlot by $0.3632 head^{-1} d^{-1}. $Cost_{int}$ equals the sum of the feeder value and half the total feed costs multiplied by the proportion of the year on feed and pasture (days on feed/365) and by 0.05 (5% interest). $Cost_d$ equals the cost of death loss and was calculated as 1.5% of feeder costs. $Cost_m$ equals marketing costs for slaughter steers and was $2 haead^{-1}. $Cost_g$ equals costs of growth promotants and were based on $1.05 per implant with 200 mg progesterone and 20 mg estradiol benzoate, $4.50 per implant with 120 mg TBA and 24 mg estradiol, and $8.50 head^{-1} for supplementation with 200 mg head^{-1} d^{-1} of ractopamine hydrochloride 28 d before slaughter.

The economic data were also adjusted for overweight carcasses since marketing overweight cattle was not a function of the production system, implant program or feed additive but rather the abattoir's availability to process the cattle. Most steers were processed on time; however, some groups of yearling-fed implanted steers were delayed by 2 wk. The overweight adjustment was calculated by determining the number of days of gain over 430.9 kg as follows: Days over = (hot carcass weight − 430.9 kg)/ADG. A new hot carcass weight was then calculated as follows: New hot carcass weight = hot carcass weight – (Days over × ADG). Feed, yardage, and interest costs and weight discounts were then adjusted accordingly. Days over for calf-fed no implant, calf-fed implant, yearling-fed no implant and yearling-fed implant were 0, 0, 1.5 (SD = 3.4), and 12.2 (SD = 14.1) d, respectively.

Statistical Analysis

All data with the exception of percentage data were subjected to an analysis of covariance using PROC MIXED (SAS Institute, Inc. 2009). Preweaning, weaning and GrowSafe® finishing data included the fixed effects of production system (calf-fed; yearling-fed), production year (1; 2), growth implant group (not implanted; implanted), breed group of sire (British; Continental) and all two-, three- and four-way interaction terms, with cow age as the covariate. The random effect of sire nested within breed group of sire was also included in the model. Animal data for backgrounding (fall pasture, feedlot backgrounding and summer pasture) were analyzed similarly, with the exception that production system and all interactions with production system were removed from the model since only yearling-fed steers go through an extended backgrounding period. A third model was used to analyze the data for the finishing period when the steers were moved from the GrowSafe® feeding stations (individual animal feed intake) into eight small pens (group feed intake) in preparation for the feeding of the β-agonist during the last 28-d before slaughter. This model included the fixed effects of production system (calf-fed; yearling-fed), production year (1; 2), growth implant group (not implanted; implanted), β-agonist (no ractopamine; ractopamine), breed group of sire (British; Continental) and all two-, three- four- and five-way interaction terms, with cow age as the covariate. The random effects of sire nested within breed group of sire and pen nested within production system, production year, implant group and β-agonist group were also included in the model. Those sources of variation with significant ($P < 0.05$) F values were subjected to multiple comparisons of least squares means using the PDIFF option of SAS software (SAS Institute, Inc. 2009). Differences among fixed effects for yield and quality grade were analyzed with the PROC FREQ procedure of SAS software using the CHISQ option (SAS Institute, Inc. 2009).

RESULTS AND DISCUSSION

Steers Performance

Steers were similar across production system and implant groups in birth weight, breed cross percentage, weaning age, pre-weaning ADG and body weight when the calf-fed steers entered the feedlot and the yearling-fed steers went onto pasture in mid-October (Table 4). Except for the fall grower period, implanted yearling-fed steers grew faster than non-implanted yearling-fed steers. During the 42 d of the fall grower phase, non-implanted yearling-fed steers grew 0.12 kg d^{-1} faster than implanted yearling-fed steers; however, this was over a short feeding period and final weight at the end of the fall grower phase did not differ between implant treatments. During the 191 d feedlot and 66 d summer pasture backgrounding phases, yearling-fed implant steers grew 7.6 and 9.9% faster than did non-implanted yearling-fed steers. Implanted yearling-fed steers had less backfat and marbling, consumed 5.5% more feed and were 10 kg heavier than their non-implanted pen mates during feedlot backgrounding, and 17 kg heavier at the end of summer grazing. Implanted yearling-fed steers did tend to be more efficient than non-implanted yearling-fed steers during the summer grazing, but not during the feedlot backgrounding period. Numerous studies have reported similar performance advantages for implanted steers and the fact is widely known (Foutz et al. 1997; Reiling and Johnson 2003; Reinhardt 2007).

Calf-fed and yearling-fed steer performance in the feedlot is presented in Table 5. Calf-fed steers were 191 d of age at the start of the finishing dietary adjustment period, and they spent a total of 196.5 d in the feedlot.

Table 4. Effects of production system (calf-fed vs. yearling-fed) and growth promotants on production traits from weaning through the backgrounding or grower phase

	Calf-fed		Yearling-fed			*P* values		
Item	Non-implant ($n=56$)	Implant ($n=56$)	Non-implant ($n=56$)	Implant ($n=56$)	SEM	System	Implant	System × Implant
Birth weight (kg)	43.2	42.9	43.8	43.3	1.0	0.466	0.595	0.868
British (%)	51.8	55.5	52.0	51.9	2.7	0.279	0.233	0.217
Continental (%)	48.2	44.5	48.0	48.1	2.7	0.279	0.233	0.217
Weaning age (d)	191	190	193	192	3	0.179	0.495	0.637
Weaning weight (kg)	267.2	268.0	265.8	266.8	4.6	0.741	0.803	0.979
Pre-weaning ADG (kg d^{-1})	1.18	1.19	1.15	1.17	0.02	0.184	0.452	0.821
Backgrounding or grower period								
Days on fall pasture[z]	–	–	42	42	–	–	–	–
Fall pasture, ADG (kg d^{-1})	–	–	0.12*b*	0.00*a*	0.06	–	0.005	–
Fall pasture, end weight (kg)	–	–	271.9	269.3	4.0	–	0.621	–
Fall pasture, DMI (kg DM d^{-1})	–	–	NA	NA	NA	–	NA	–
Feedlot, days on feed[y]	–	–	191	191	–	–	–	–
Feedlot, ADG (kg d^{-1})	–	–	0.92*a*	0.99*b*	0.02	–	0.004	–
Feedlot, end backfat (mm)	–	–	6.6*b*	5.5*a*	0.4	–	0.037	–
Feedlot, end ribeye area (cm^2)	–	–	65.1	63.5	1.1	–	0.311	–
Feedlot, end marbling	–	–	4.67	4.50	0.07	–	0.096	–
Feedlot, DMI (kg DM d^{-1})	–	–	7.80*a*	8.25*b*	0.12	–	0.018	–
Feedlot, FCR (kg DMI kg^{-1} gain)	–	–	8.46	8.42	0.22	–	0.912	–
Feedlot, end weight (kg)	–	–	447.9	458.7	6.7	–	0.118	–
Days on summer pasture[x]	–	–	66	66	–	–	–	–
Summer pasture, ADG (kg d^{-1})	–	–	0.51*a*	0.59*b*	0.03	–	0.028	–
Summer pasture, DMI (kg DM d^{-1})	–	–	14.83	13.64	0.45	–	0.102	–
Summer pasture, FCR (kg DMI kg^{-1} gain)	–	–	33.85	28.64	1.82	–	0.078	–
Summer pasture, end weight (kg)	–	–	481.7*a*	499.0*b*	6.3	–	0.012	–

[z]Fall pasture was alfalfa meadow bromegrass and was grazed for 52 d in 2008 and 31 d in 2009.
[y]The backgrounding period was 192 d in 2008/09 and 189 d in 2009/2010.
[x]Summer pasture was alfalfa meadow bromegrass and was grazed for 59 d in 2009 and 74 d in 2010.
a, *b* Least squares means with different letters differ at $P<0.05$.

Yearling-fed steers were 491 d of age at the start of their dietary adjustment period and spent a total of 337 d in the feedlot; 191 d were spent in the backgrounding feedlot and 146 d in the finishing feedlot. Calf-fed steers were given 12–13 more days to adjust to the high-energy finishing diet than yearling-fed steers since yearling-fed steers were on average 10 mo older, 222 kg heavier, had a more developed rumen and had previously adapted to a barley-grain–silage diet during the winter backgrounding phase. Once the dietary adjustment had ended, yearling-fed steers spent 38 fewer days in the finishing feedlot than calf-fed steers (124 vs. 162 d; $P<0.01$) due to their rapid compensatory growth rate and because their backfat thickness target end point of 8–10 mm was reached earlier. Non-implanted and implanted yearling-fed steers were 214 and 231 kg, respectively, heavier than their calf-fed counterparts at the beginning of the dietary adjustment period. In addition, implanted yearling-fed steers were 17.3 kg heavier (3.5%) than non-implanted yearling-fed steers, while implanted and non-implanted calf-fed steers were similar in body weight. This result was expected as calf-fed steers had just been implanted with their first growth implant and yearling-fed steers had received four growth implants.

During the dietary adjustment period, calf-fed steers grew 64.5% slower (1.21 vs. 1.99 ± 0.07 kg d^{-1}; $P<0.001$), consumed less feed (7.02 vs. 10.09 ± 0.34 kg DMI d^{-1}; $P<0.001$) and had a poorer FCR (5.32 vs. 4.99 ± 0.34 kg DMI kg^{-1} gain; $P=0.06$) than yearling-fed steers, possibly reflecting weaning stress and the requirement for the rapid adaptation of their rumen microbes to a diet high in concentrates (Brown et al. 1998). In addition, yearling-fed steers were older and may have, a more developed rumen, had previously adapted to a silage-barley grain diet during the backgrounding period and were undergoing compensatory gain due to a long period of growth. This result is also reflected in the ADG during this period where non-implanted and implanted yearling-fed steers grew 37.4% and 40.6% faster than their calf-fed counterparts.

Implanted calf-fed steers grew 13.8% faster, were similar in DMI and had a 14.9% better FCR than non-implanted calf-fed steers during their 34.5 d feedlot adjustment period, while yearling-fed steers grew 18.3% faster, consumed 6.1% more feed and had a 15.1% better FCR than non-implanted yearling-fed steers during their 22 d feedlot adjustment period. Similarly, implanted calf-fed steers grew 15.3% faster during the

Table 5. Effects of production system (calf-fed vs. yearling-fed) and growth promotants on production traits during finishing

	Calf-fed		Yearling-fed			*P* values			
Item	Non-implant	Implant	Non-implant	Implant	SEM	System	Implant	System × Implant	β-agonist
Finishing, adjustment period									
Dietary adjustment[z] (d)	34.5*b*	34.5*b*	22.0*a*	22.0*a*	0.03	<0.001	0.538	0.561	–
Initial weight (kg)	268.0*a*	268.3*a*	481.7*b*	499.0*c*	5.4	<0.001	0.041	0.047	–
ADG[y] (kg d^{-1})	1.12*a*	1.30*a*	1.79*b*	2.19*c*	0.09	<0.001	<0.001	0.189	–
DMI[y] (kg DM d^{-1})	6.37*a*	6.43*a*	9.55*b*	10.17*c*	0.19	<0.001	0.029	0.066	–
FCR[y] (kg DMI kg^{-1} gain)	5.69*b*	4.95*a*	5.34*b*	4.65*a*	0.15	0.063	0.002	0.521	–
Finishing, individual animal feed intake									
Days on feed[x]	83	83	76	76	1	<0.001	0.462	0.441	–
Initial weight (kg)	307.7*a*	314.2*a*	521.9*b*	547.0*c*	6.3	<0.001	0.001	0.055	–
Initial ultrasound backfat (mm)	3.5*a*	3.7*a*	5.6*c*	4.7*b*	0.2	<0.001	0.033	0.002	–
Initial ultrasound ribeye area (cm^2)	50.8*a*	53.3*b*	71.0*c*	72.5*c*	0.9	<0.001	0.013	0.541	–
Initial ultrasound marbling score	4.02*a*	3.98*a*	4.64*c*	4.38*b*	0.06	<0.001	0.012	0.075	–
ADG (kg d^{-1})	1.49*a*	1.76*b*	1.71*b*	1.98*c*	0.04	<0.001	<0.001	0.974	–
End weight (kg)	429.7*a*	461.2*b*	650.7*c*	696.5*d*	8.2	<0.001	<0.001	0.219	–
End ultrasound backfat (mm)	8.2*a*	8.6*a*	10.3*b*	9.8*b*	0.3	<0.001	0.935	0.115	–
End ultrasound ribeye area (cm^2)	71.2*a*	76.7*b*	85.9*c*	91.4*d*	1.1	<0.001	<0.001	0.977	–
End ultrasound marbling score	4.71*b*	4.45*a*	5.20*d*	4.91*c*	0.06	<0.001	<0.001	0.784	–
DMI (kg DM d^{-1})	8.03*a*	8.52*b*	12.40*c*	13.88*d*	0.20	<0.001	<0.001	<0.001	–
FCR (kg DM kg^{-1} gain)	5.46*b*	4.86*a*	7.42*c*	7.25*c*	0.14	<0.001	0.005	0.111	–
Finishing, pen feed intake									
Days on feed (d)	79*b*	79*b*	48*a*	48*a*	9	0.005	0.986	0.984	0.075
ADG (kg d^{-1})	1.48*b*	1.67*b*	0.90*a*	1.12*a*	0.11	<0.001	0.075	0.916	0.295
DMI (kg DM d^{-1})	8.55*a*	9.04*b*	11.72*c*	12.48*d*	0.18	<0.001	0.004	0.488	0.436
FCR (kg DM kg^{-1} gain)	5.95*a*	5.42*a*	15.42*b*	13.15*b*	2.23	<0.001	0.520	0.688	0.292
Age at slaughter (mo)	13.0*a*	12.9*a*	21.2*b*	21.2*b*	0.3	<0.001	0.819	0.976	0.104
Slaughter weight (kg)	544.9*a*	582.0*b*	694.9*c*	754.3*d*	7.1	<0.001	<0.001	0.099	0.718
HCW[y] (kg)	319.2*a*	344.7*b*	412.7*c*	451.6*d*	4.1	<0.001	<0.001	0.120	0.086
Yield grade - Y1 (%)	33.9	32.1	29.1	25.0					
- Y2 (%)	42.9	50.0	49.1	53.6					
- Y3 (%)	23.2	17.9	21.8	21.4		0.613	0.680	0.924	0.311
Quality grade- AAA (%)	35.7	21.8	43.6	16.1					
- AA (%)	57.1	69.1	54.6	69.6					
- A (%)	7.2	9.1	1.8	8.9					
- B4 (%)	0.0	0.0	0.0	5.4		0.305	0.002	0.008	0.096

[z]The adjustment period was 27 d in 2008 and 42 d in 2009 for calf-fed steers, and 21 d in 2009 and 23 d in 2010 for yearling-fed steers.
[y]ADG, average daily gain; DMI, dry matter intake; FCR, feed conversion ratio; HCW, hot carcass weight.
[x]Recording of individual animal feed intake was 86 d in 2008 and 80 d in 2009 for calf-fed steers, and 76 d in 2009 and 2010 for yearling-fed steers.
a–d Least squares means with different letters differ at $P < 0.05$.

first 83 d and 11.4% faster during the latter 79 d of the finishing period compared with non-implanted calf-fed steers. Implanted yearling-fed steers also grew faster during the first 76 d (13.6%) and latter 48 d (19.6%) of their finishing period compared with non-implanted yearling-fed steers. DMI primarily reflects differences in ADG and body weight, with yearling-fed being much heavier than calf-fed steers and implanted steers growing faster than non-implanted steers. FCR during the first 76–83 d of the finishing period differed by production system and implant group, with calf-fed steers being more efficient than yearling-fed steers (5.16 vs. 7.33 ± 0.11 kg DMI kg^{-1} gain; $P < 0.001$) and implanted steers being more efficient than non-implanted steers (6.05 vs. 6.44 ± 0.11 kg DMI kg^{-1} gain; $P < 0.005$).

Similarly, FCR during the last 48–79 d of the finishing period differed by production system, with calf-fed steers being more efficient than yearling-fed steers (5.69 vs. 14.28 ± 1.50 kg DMI kg^{-1} gain; $P < 0.001$), and implanted steers being numerically more efficient than non-implanted steers (9.29 vs. 10.69 ± 1.50 kg DMI kg^{-1} gain; $P = 0.520$). Feed efficiency decreased much more rapidly in the yearling-fed steers due to their later stage of maturity, and increased subcutaneous and intramuscular fat compared with calf-fed steers. Previous studies carried out with calf-fed and yearling-fed production systems showed feedlot average daily gain was greater for yearling-fed steers, while feedlot feed efficiency was better for calf-fed steers (Anderson et al. 2005; Griffin et al. 2007). In addition, numerous authors (Myers et al. 1999a, b; Fluharty et al. 2000; Schoonmaker et al. 2002, 2004) have shown that calf-fed steers fed a high-concentrate diet are very efficient in conversion of feed to gain. Besides, implanted calves grow faster and are leaner through all phases of the production cycle and are more efficient than non-implanted calves.

Calf-fed are more efficient than yearling-fed cattle due to reduced liver and reticulo-rumen weights that are metabolically active tissues requiring up to 40% of the energy required for maintenance.

Carcass Characteristics

Yearling-fed steers harvested at 19–23 mo of age were about 8 mo older than calf-fed steers that were harvested at 11–15 mo of age (Table 5). Slaughter weight and hot carcass weights were affected by production system ($P < 0.001$) and implant treatment ($P < 0.001$) such that yearling-fed implanted steers yielded the heaviest carcasses by 38.9, 106.9 and 132.4 kg compared with non-implanted yearling-fed, implanted calf-fed and non-implanted calf-fed steers, respectively. During the finishing period, yearling-fed steers had more ultrasound backfat thickness, marbling and rib-eye area than calf-fed steers, and implanted steers were leaner and had a larger rib-eye area than non-implanted steers. However, no differences ($P > 0.1$) were noted across productions systems or implant groups in yield grade, since the steers were targeted for slaughter at a constant backfat thickness. Approximately half the carcasses graded Y2 and the production system by implant groups ranged from 42.9% Y2 for non-implanted calf-fed to 53.6% for implanted yearling-fed steers. Brewer et al. (2007) in a study with implanted steers found heavier yearling-finished carcasses (375.9 vs. 315.4 kg) from steers slaughtered at 19–20 mo of age compared with calf-finished steers slaughtered at 13–14 mo of age. Previous studies have reported heavier carcass weight in implanted compared with non-implanted steers (Roeber et al. 2000). Herschler et al. (1995) and Foutz et al. (1997) also reported that carcasses from steers implanted with a combination of estrogen benzoate and TBA were heavier and had larger rib-eye area than carcasses from non-implanted steers. Numerous studies have reported that implants decrease quality grade and marbling score in beef (Roeber et al. 2000; Reiling and Johnson 2003; Reinhardt 2007). Consistent with these findings, implanting affected quality grade in calf-fed ($P < 0.052$) and yearling-fed ($P < 0.001$) steers. In the yearling-fed system, 43.6% of non-implanted steers and 16.1% of implanted carcasses were graded AAA. Calf-fed non-implanted steers showed a higher AAA quality grade frequency (35.7%) compared with the calf-fed implanted (21.8%) steers. In addition, yearling-fed implanted steers had 5.4% dark cutting carcasses (B4) compared with 0.0% for the other production system by implant groups. The reason for this observation is uncertain though availability of mobile fats in the muscle may have been a factor. Previous studies (Herschler et al. 1995; Scanga et al. 1998) have reported darker longissimus muscle color or greater incidence of “dark cutters” when implants were used. In contrast, Foutz et al. (1997) did not detected “dark cutting” issues in a study with implanted yearling steers (predominantely Limousin × British), likewise, Van Weerden (1984) observed that muscle color in veal calves was generally unaffected by treatment with anabolics. In the present study, dark cutting incidences were only observed in the yearling steers.

Brewer et al. (2007), in a study with implanted steers, reported that carcasses from calf-fed steers had greater marbling scores and hence quality grades than carcasses from yearling-fed steers. On the other hand, Wertz et al. (2002) suggested that the increased length of time on a high-concentrate diet likely accounted for the higher extractable lipid values. These authors concluded that early-weaning heifers and finishing them in an accelerated program allows intramuscular fat deposition while heifers are gaining more efficiently compared with heifers grown on pasture and finished as 2-yr-olds.

Economics

A summary of economic evaluation of calf-fed and yearling-fed production systems and implant treatment is presented in the Table 6. No differences were observed between production systems and implanting treatments for initial feeder, transportation and induction costs. Feed costs were significantly affected ($P < 0.001$) by beef production system, such that they were 57% or \$222.30 head^{-1} higher for non-implanted yearling-fed steers compared with non-implanted calf-fed steers. Similarly, feed costs were 64% or \$258.21 head^{-1} higher for implanted yearling-fed steers compared with implanted calf-fed steers. Feed cost for implanting was \$10.68 head^{-1} higher for calf-fed and \$46.59 head^{-1} higher for yearling-fed compared with their non-implanted cohorts. This was due to increased feed consumption by implanted steers as they were heavier throughout most of their production cycle than non-implanted steers. In contrast to these findings, Griffin et al. (2007) in a study with implanted steers reported greater feed cost for calf-fed compared with long yearling-fed cattle. In that study, animals were sorted by body weight and the heavier animals entered into an intensive calf-feeding system and the lighter animals into an extensive long yearling-feeding system. In addition, these authors found a higher initial animal cost for calf-fed cattle compared with long yearling-fed cattle because the calf-feds were 53 kg heavier at entry into the feedlot.

As expected, yardage costs for the yearling-fed steers averaged \$50.47 head^{-1} greater than for calf-fed steers. Interest per head was over twice as high for the yearling-fed compared with calf-fed steers. Total costs were significantly affected by the production system, implanting program and β-agonist supplementation. Total costs for non-implanted yearling-fed steers were 27% or \$303.74 head^{-1} higher than total costs for non-implanted calf-fed steers. Similarly, total costs for implanted yearling-fed steers were 30% or \$344.68 head^{-1} higher than for implanted calf-fed steers. Implanting increased total costs by 1.5% in calf-fed steers and 4.0% in yearling-fed steers primarily due to the cost of growth implants and increased feed costs since implanted steers

Table 6. Effects of production system (calf-fed vs. yearling-fed), growth promotants and β-agonist supplementation on economic traits during finishing

	Calf-fed		Yearling-fed			*P* values			
Cost (\$ head^{-1})	Non implant ($n=56$)	Implant ($n=56$)	Non implant ($n=56$)	Implant ($n=56$)	SEM	System	Implant	System × Implant	β-agonist
Feeder	601.92	602.19	597.80	600.12	12.43	0.806	0.917	0.935	0.089
Transportation	10.20	10.15	10.15	10.20	–	–	–	–	–
Veterinary/med.	18.06	18.07	17.93	18.00	0.37	0.806	0.917	0.935	0.089
Feed	392.27*a*	402.95*a*	614.57*b*	661.16*c*	18.14	<0.001	0.132	0.334	0.052
Yardage	71.38*a*	71.22*a*	121.77*b*	121.77*b*	3.38	<0.001	0.981	0.981	0.075
Interest	21.53*a*	21.60*a*	55.05*b*	56.58*b*	1.11	<0.001	0.482	0.520	0.103
Death loss	9.03	9.03	8.97	9.00	0.19	0.806	0.917	0.935	0.089
Marketing costs	2.00	2.00	2.00	2.00	–	–	–	–	–
Implant/RAC	4.25	9.80	4.10	11.90	–	–	–	–	–
Total cost	1130.30*a*	1146.91*a*	1434.04*b*	1491.59*c*	14.06	<0.001	0.016	0.160	0.046
Income	1087.26*a*	1163.30*b*	1317.59*c*	1343.61*c*	18.46	<0.001	0.010	0.178	0.226
Net return	−42.38*b*	17.04*c*	−115.30*a*	−147.45*a*	21.25	0.001	0.521	0.042	0.696
Adjusted net return based on Alberta monthly average slaughter rail price									
–2006–2010	−41.92*b*	17.52*c*	−99.65*a*	−73.77*ab*	19.48	0.001	0.039	0.392	0.773
–2006	−115.18*a*	−65.56*ab*	−30.27*bc*	−1.50*c*	33.67	0.007	0.104	0.621	0.723
–2007	40.70*b*	106.56*c*	−93.53*a*	−67.41*a*	26.59	<0.001	0.099	0.461	0.497
–2008	−75.97	−20.77	−121.89	−97.12	30.09	0.057	0.198	0.617	0.266
–2009	−7.75*b*	54.58*b*	−112.19*a*	−87.17*a*	30.59	<0.001	0.169	0.547	0.219
–2010	−49.33*bc*	7.97*c*	−140.70*a*	−116.71*ab*	44.13	0.026	0.369	0.710	0.189

Feeder prices for each weight class (e.g., 500–600 lb) were taken from the *Weekly Livestock Market Review* for the week ending 2008 Oct. 17 for central Alberta (http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/sdd6247).
Transportation of the feeder to the feedlot was \$10.15 head^{-1} (Canfax Trends 2008).
Veterinary and medicines were calculated as 3% of feeder cost (Canfax Trends 2008).
Feed cost were \$0.232 kg^{-1} DM.
Death loss was 1.5% of feeder cost (Canfax trends 2008).
Marketing cost of finished cattle was \$2.00 head^{-1} (Canfax Trends 2008).
Yardage was \$0.3632 head^{-1} d^{-1}.
Interest was the sum of the feeder cost and half the feed cost multiplied by the proportion of the year on feed (days on feed/365) and by 0.05 (5% interest) (Basarab et al. 1999).
Implant cost was \$1.50 head^{-1} implant^{-1} (Elanco Animal Health).
Ractopamine hydrochloride cost was \$8.50 head^{-1} (Elanco Animal Health).
Base rail grade price was taken from a 5-yr (2006–2010) monthly average of Alberta rail grade sale prices and for each year (http://www1.agric.gov.ab.ca/\$department/deptdocs.nsf/all/sdd6247).
Carcass premiums and discounts were \$12, \$3 and \$0/cwt for AAA, AA, and A quality grades and \$0, \$–3 and \$–10/cwt for 1, 2 and 3 yield grades.
Carcass weight discounts were \$15/cwt for carcass weighing less than 550 lb, \$0/cwt for carcass between 550 and <950 lb, \$–7.50/cwt for carcass between 950 and <1000 lb and \$–15/cwt for carcass = 1000 lb.
Income equals carcass weight multiplied by base rail grade price minus carcass discounts plus carcass premiums.
a–c Least squares means with different letters differ at $P<0.05$.

are heavier than non-implanted steers throughout most of their production cycle and consumed 6–12% more feed during the backgrounding and finishing periods. Steers supplemented with β-agonist had higher total costs due to the cost of the feed additive and more days in the finishing feedlot (133 vs. 151 d, $P=0.075$) than non-supplemented steers. This result is not a true reflection of the economic value of ractopamine since cattle ready for slaughter based on ultrasound backfat thickness and body weight were not available for the β-agonist treatment.

Income also differed by production system and implant regime. Non implanted yearling-fed steers received 21% or \$230.33 head^{-1} more income than non-implanted calf-fed steers due to heavier carcass weights. Similarly, implanted yearling-fed steers received 15% or \$180.31 head^{-1} more income than implanted calf-fed steers, again due to heavier carcass weights. Implanting increased income by 7% in calf-fed and 2% in yearling-fed steers. The adjusted net return was most profitable for implanted calf-fed and then non-implanted calf-fed steers. This result would have occurred in 4 of 5 yr from 2006 to 2010 due to their lower production costs and longer-term trend in monthly rail price, where rail price increased during the months of March through June when calf-fed steers were sold and decreased from November through January when yearling-fed steers were sold. The adjusted net return was least profitable for non-implanted yearling-fed steers primarily because of relatively higher costs and lower income compared with implanted yearling-fed steers. These results are similar to those of an Oklahoma study where profitability tended to favor the calf-fed over the yearling-fed system (Winterholler et al. 2008a). In that study fall-weaned calves sent directly to the feedlot were compared with fall-weaned calves grazing wheat pasture before feedlot entry. Small et al. (2009) reported that the profitability of calf-fed and yearling-fed systems were, on average, similar, but the calf-fed system showed less profit variability suggesting more inherent risk in the yearling-fed system. Contrary to these findings, Shain et al. (2005) concluded that overall productivity of a beef production system can be improved by maximizing forage body weight gain, and by grazing complementary summer and/or fall forages. Several other studies point to carcass weight (Tatum et al. 2006) and body weight (Klopfenstein et al. 2000; Shain et al. 2005) being the most important factors affecting profitability. However, there are many factors affecting profitability of the cattle production systems. In the design of the present study, production systems, implant groups and feed additive groups (calf-fed vs. yearling-fed; no implant vs. implant; no β-agonist vs. β-agonist) were constructed to create substantial variation in production economics, carcass and meat quality.

Eng (2006) estimated that in the United States of America more feeder cattle move through the yearling-fed (76%) vs. calf-fed (24%) production system, whereas Basarab et al. (2009) estimated that in Canada this ratio is closer to 55:45 in favor of the yearling-fed beef production system. Several studies (Griffin et al. 2007; Winterholler et al. 2008a) have reported that profitability is variable between calf-fed and yearling-fed production systems. On the other hand, reports from the US cattle industry through the VetLife database, containing production and carcass data on millions of cattle, indicated that slaughtering cattle at a younger age (<15 mo) was more profitable when feed grain prices were high (Eng 2006). The results of the present study agree that reducing age at slaughter increased profitability when combined with growth promotants. It is important to note that profits are influenced by fluctuations in the prices across the years and seasons. In the present study seasonality and price-slide were taken into account in the economic analysis. The present data may be used to make recommendations on alternative production systems that reduce cost without compromising carcass quality and greenhouse gas emissions (Basarab et al. 2011).

CONCLUSIONS

Currently, there are many systems of management used to produce beef cattle. Consumers demand affordable, safe beef and as a result the beef cattle industry demands technology that provides cost effective improvements in performance. Calf-fed beef production systems improved feed efficiency and profitability, but decreased growth rate and carcass weight. Yearling-fed productions systems improved growth rate and carcass weight, but decreased feed efficiency, carcass quality and profitability. Growth implants increased feed intake and daily gain, improved feed efficiency and profitability, and decreased carcass grade. Results of the present study suggest that reducing age at slaughter combined with growth implant can reduce the cost of production, increase profit and reduce risk; however, growth implants can also negatively affect quality grade.

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