Alternative fall and winter feeding systems for spring calving beef cows

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[1]*Western Forage/Beef Group, Agriculture and Agri-Food Canada, Research Centre, 6000 C & E Trail, Lacombe, Alberta, Canada T4L 1W1 (e-mail: mccartneyd@em.agr.ca);* [2]*Western Forage/Beef Group, Alberta Agriculture, Food and Rural Development, Research Centre, 6000 C & E Trail, Lacombe, Alberta, Canada T4L 1W1;* [3]*Department of Food, Nutritional and Agricultural Sciences, University of Alberta, Edmonton, Alberta, Canada T6G 2P5.* *Received 14 July 2003, accepted 8 April 2004.*

McCartney, D., Basarab, J. A., Okine, E. K., Baron, V. S. and Depalme, A. J. 2004. **Alternative fall and winter feeding systems for spring calving beef cows**. Can. J. Anim. Sci. **84**: 511–522. This study evaluated the effects of early (EW) and late (LW) weaning on calf post-weaning growth performance and carcass characteristics. It also quantified the effects of EW and LW in combination with three winter feeding strategies on cow growth, reproductive performance and cost of production. EW calves were weaned in late August, while LW calves were weaned 56 d later in late October. The three cow winter feeding strategies were: (1) traditional (TD), or straw fed ad libitum and barley (*Hordeum vulgare* L.) silage fed every day; (2) alternate day (AD), or straw fed ad libitum and equivalent amounts of barley silage fed every second day (AD); and (3) swath graze (SG), or swath grazing whole-plant barley, cut in the soft dough stage. The study was conducted over three production cycles (1997/1998, 1998/1999 and 1999/2000). EW calves weighing 213 kg and fed a backgrounding diet (82% barley silage: 18% concentrate) for 56 d, grew 0.36 kg d^{-1} (EW = 0.61 ± 0.02 kg d^{-1}; LW = 0.97 ± 0.02 kg d^{-1}; $P < 0.001$) slower from early to late weaning than LW calves (210 kg) on pasture nursing their mothers. Over the next 124–128 d, EW and LW calves fed the backgrounding diet grew similarly at 0.95 ± 0.01 and 0.93 ± 0.02 kg d^{-1}, respectively. Both groups of calves also grew similarly during the finishing phase (EW = 1.56 ± 0.04 kg d^{-1}; LW = 1.53 ± 0.05 kg d^{-1}; $P = 0.62$), such that at slaughter, EW and LW calves were the same age (461 ± 4 vs. 455 ± 5 d, $P = 0.326$) and weight (522 ± 5 vs. 515 ± 6 kg, $P = 0.390$), with similar levels of carcass backfat, yield and quality grade. EW cows weighed 12 to 15 kg more ($P < 0.01$) in mid-November (first winter feeding), mid-February (pre-calving) and late-May (prebreeding) and tended to have a shorter calving span (49 vs. 62 d, $P = 0.07$) than the LW cows. Calving interval, calving pattern and cumulative open and cull rates, monitored over three consecutive production cycles, were similar for EW and LW cows. Differences ($P < 0.05$) in body weight were observed between winter feeding treatments. SG cows had the lowest weight (605 kg) and backfat thickness (4.5 mm) at pre-breeding; AD cows were intermediate (623 kg and 5.1 mm); and TD cows were heaviest (639 kg) with the most backfat (6.4 mm). Calving interval, length of the calving span, calving pattern and cumulative open and cull rates were similar among the winter feeding strategies for cows monitored over three production cycles. Swath grazing required 38.4% less labour than traditional feeding and 20.9% less labour than alternate day winter feeding. Total cash cost over the first 100 d of winter feeding for the SG winter feeding strategy was \$70.00 cow^{-1} less than TD (45.5%) and \$56.70 cow^{-1} less than AD (40.4%) winter feeding strategies. On average, 300 and 314 cow swath grazing d ha^{-1} were required to cover the cost of feed in the TD and AD winter feeding strategies, respectively.

Key words: Beef cows, Western Canadian Parkland, swath grazing, alternate day, early and late weaning

McCartney, D., Basarab, J. A., Okine, E. K., Baron, V. S. et Depalme, A. J. 2004. **Autres stratégies d'alimentation automnale et hivernale pour les vaches de boucherie vêlant au printemps**. Can. J. Anim. Sci. **84**: 511–522. Les auteurs ont évalué l'incidence d'un sevrage hâtif (SH) ou tardif (ST) sur la croissance des veaux après le sevrage et les paramètres de la carcasse. Ils ont aussi quantifié les effets du SH et du ST combinés à trois régimes d'engraissement hivernaux sur la croissance des vaches, leurs aptitudes à la reproduction et les coûts de production. Les veaux SH ont été sevrés à la fin d'août alors que les veaux ST l'ont été 56 jours plus tard, à la fin d'octobre. Les trois régimes d'engraissement hivernaux étaient les suivants : (1) régime classique (RC) composé de paille servie à satiété et d'ensilage d'orge (*Hordeum vulgare*) tous les jours; (2) régime un jour sur deux (UD), soit paille servie à satiété et équivalent d'ensilage d'orge servi un jour sur deux; (3) paissance sur andains (PA), où les bêtes broutaient des andains d'orge entière récoltée au stade pâteux mou. L'étude s'est déroulée sur trois cycles de production (1997/1998, 1998/1999 et 1999/2000). Du début à la fin du sevrage, les veaux SH pesant 213 kg et recevant une ration de semi-finition (82 % d'ensilage d'orge; 18 % de concentré) pendant 56 jours ont gagné 0,36 kg de moins par jour que les veaux ST (210 kg) mis à l'herbe qui tétaient leur mère (SH = 0,61 ± 0,02 kg par jour; ST = 0,97 ± 0,02 kg par jour; $P < 0,001$). Au cours des 124 à 128 jours suivants, les veaux SH et ST nourris avec la ration de semi-finition ont grossi au même rythme et gagné 0,95 ± 0,01 et 0,93 ± 0,02 kg par jour, respectivement. Les deux groupes ont aussi gagné du poids de façon analogue pendant la finition (SH = 1,56 ± 0,04 kg par jour; ST = 1,53 ± 0,05 kg par jour; $P = 0,062$), si bien qu'à l'abattage, les sujets des deux groupes avaient le même âge (461 ± 4 c. 455 ± 5 jours, $P = 0,326$) et un poids identique (522 ± 5 c. 515 ± 6 kg, $P = 0,390$). Leur carcasse avait aussi la même épaisseur de gras dorsal et a donné le même rendement et la même qualité de viande. Les vaches SH pesaient 12 à 15 kg de plus ($P < 0,01$) à la mi-novembre (première ration d'hiver), à la mi-février (pré-vêlage) et à la fin de mai (avant l'accouplement) et avaient tendance à avoir une plus courte fourchette de vêlage que les vaches ST (49 c. 62 jours, $P = 0,07$). Observés pendant trois cycles de production, l'intervalle de vêlage, le mode

Abbreviations: **AD**, alternate day feeding of 2 days' equivalent of barley silage; **ADG**, average daily gain; **BCS**, body condition score; **DM**, dry matter; **EW**, early weaning; **LW**, late weaning; **SG**, swath grazing; **TD**, traditional feeding straw and barley silage every day

de vêlage ainsi que le taux cumulatif de vaches vides et de vaches réformées étaient similaires pour les sujets SH et ST. Les auteurs ont noté une variation ($P < 0,05$) du poids corporel pour les différents régimes d'engraissement. Les vaches PA avaient le poids (605 kg) et la couche de gras dorsal (4,5 mm) les plus faibles avant l'accouplement; les valeurs étaient intermédiaires (623 kg et 5,1 mm) pour les vaches UD; enfin, les vaches RC étaient les plus lourdes (639 kg) et avaient le plus de gras dorsal (6,4 mm). Les animaux examinés pendant trois cycles de production présentaient un intervalle de vêlage, une fourchette de vêlage, un mode de vêlage et des taux cumulatifs de vaches libres et réformées semblables pour les trois régimes d'engraissement hivernaux. La paissance sur andains réclame 38,4 % moins de main-d'œuvre que le régime classique et 20,9 % moins que le régime un jour sur deux. La paissance sur andains a coûté 70 $ par vache de moins que le régime classique (45,5 %) et 56,70 $ de moins par vache que le régime un jour sur deux (40,4 %) pour les 100 premiers jours de l'alimentation hivernale. En moyenne, il faut nourrir les vaches sur andains pendant 300 et 314 jours par hectare pour couvrir le coût des régimes hivernaux RC et UD, respectivement.

Mots clés: Vaches de boucherie, forêts-parcs de l'Ouest canadien, paissance par andain, un jour sur deux, sevrage hâtif et tardif

In the Aspen Parkland of western Canada, feeding and managing the beef cow through the winter is the single most important cost to beef production, accounting for 60–65% of the total cost of production in a cow-calf operation (Kaliel and Kotowich 2002). Generally, 200 winter feeding days are required in the central and northern Aspen Parkland of western Canada. It is estimated that for every day a cow remains on pasture in the fall a savings of at least \$0.25 head^{-1} d^{-1} accrues (Anonymous 1998). This saving does not include the cost of operating the cattle wintering facility, harvesting and handling hay, or manure removal.

Winter feeding costs have been reduced by various alternative winter feeding and grazing systems throughout North America. Generally, conserved feeding is more expensive than grazing due to machine costs during harvest (D'Souza et al. 1990). Grazing winter wheat and corn in late fall improved cow energy reserves and reduced costly feed inputs prior to calving under southern Alberta conditions (Willms et al. 1993) and grazing perennial grass meadows cost less than conserved feed in Nebraska (Adams et al. 1994). Several investigations have evaluated perennial species for stockpiled grazing throughout North America as a means of extending the grazing season and reducing winter feeding costs (Houseal and Olson 1996; Hollingsworth-Jenkins et al. 1996; Ocumpaugh and Matches 1977).

Swath grazing whole-plant small-grain cereals in winter is a technique used to extend the grazing season for beef cows on the Canadian prairies (Anonymous 1998; Entz et al. 2002). Savings due to winter grazing may accrue through reduced harvesting, handling, feeding and manure removal costs (Hitz and Russel 1998; Johnson and Wand 1999; Volesky et al. 2002). However, the long-term reproductive and growth performance of cows, the extra energy requirement for foraging through the snow and the economic costs associated with swath grazing have not been quantified under western Canadian conditions.

Alternate day feeding of energy supplements, such as grain, silage or hay, has the potential for reducing winter feeding costs. Alberta research (Rob Hand, personal communication, AAFRD 1999) indicated a 28% savings in labour and equipment costs for alternate day *ad libitum* feeding of hay and straw. There were no adverse effects on feed intake and digestion. Varying frequency of feeding protein and barley supplements to steers (465 ± 30 kg) in a metabolic study had no influence on barley straw intake, total feed intake, disappearance of ruminally incubated straw, or ruminal ammonia and lactate concentrations (Tellier 2001). Intake of a cottonseed meal supplement and forage on pasture was less variable when fed at less frequent intervals than when fed every day (Huston et al. 1999). They found that reducing the frequency of feeding the cottonseed meal supplement did not significantly impact ruminal metabolism in cows. Feeding cows three times a week versus every day increased DM and neutral detergent fibre digestion (Chase and Hibbard 1989; Collins and Pritchard 1992; Beaty et al. 1994).

Early weaning may lower winter feeding costs and improve efficiency. Peterson et al. (1987) reported that calves weaned at 110 d of age were 43% more efficient in converting total digestible nutrients (TDN) into calf gain than calves weaned at 210 d of age. Peterson et al. (1987) also found that early-weaned cows consumed 20% less TDN than cows still nursing their calf. Myers et al. (1999) found that cows weaned at 170 d had 0.23 units higher BCS (scale of 1–9) than cows weaned at 225 d. Wyatt et al. (1976) concluded that early-weaned calves need to be on a growing diet that provides an ADG similar to that achieved on the cow, otherwise early-weaned calves would not finish at an acceptable slaughter weight. Thompson et al. (2001) found that spring-born, suckling calves grazing rangelands from early September to November had ADG greater than or equal to calves early weaned on Sep. 01 and grazing irrigated pastures until November. Cow weight gains fluctuated greatly among years, reflecting differences in the amount of fall re-growth available for grazing.

The objectives of this study were to determine the effects of early (EW) and late (LW) weaning on calf post-weaning growth performance and carcass characteristics, and to quantify the effects of EW and LW in combination with traditional, alternate day and swath grazing winter feeding strategies on cow growth, reproductive performance and cost of production.

MATERIALS AND METHODS

Animals and Treatments

All cattle were maintained at the Lacombe Research Centre, Lacombe, Alberta, and were cared for in accordance with the principles and guidelines set out by the Canadian Council on Animal Care (1993). One hundred and twenty-seven spring calving cows of Angus-Hereford (n = 77, AnHe, moderate frame size) and Charolais-Maine Anjou (n

= 50, ChMa, large frame size) breeding were used in this study. Cows were bred by natural service in multi-sire mating groups from Jun. 01 to Jul. 15 of each year (cow:bull ratio = 25:1). AnHe cows were bred to either purebred Aberdeen Angus or Hereford bulls used in alternating years, while ChMa cows were bred to either purebred Charolais or Maine Anjou bulls used in alternating years. A pregnancy examination was conducted in August the first year of the study and in October for the remaining years. All cows reared their own calves and were pregnant when the study began in August of 1997.

The cows were split into two equal groups based on cow weight, breed cross and date of calving. Sixty cows were early weaned (EW) in late August, while 67 cows were late weaned (LW) in late October of each year. EW and LW calves were placed in feedlot pens and fed ad libitum a backgrounding diet for 188 d (56 d plus 132 d) and 132 d, respectively. The backgrounding diet consisted of 82% barley silage, 15.3% rolled barley grain, 2.34% feedlot supplement (32% CP) and 0.36% molasses on an as-fed basis (43.9% DM, 12.8% CP, 12.69 MJ DE kg^{-1} DM). At the beginning of March of each year, the backgrounded calves were stepped up to a finishing diet over 24 d and then implanted with Ralgro FE 72 (Schering-Plough Animal Health, Omaha, NE). These calves were then randomized to feedlot pens (6–14 heifer or steer calves per pen) such that there were two to four replicates for each year, weaning treatment and gender group. The finishing diet was fed ad libitum and consisted of 22% barley silage, 73.3% rolled barley grain, 3.1% feedlot supplement (32% CP) and 1.6% molasses on an as-fed basis (75.1% DM, 13.3% CP, 14.35 MJ DE kg^{-1} DM). No feed additive to suppress oestrus was mixed into the finishing diet for feeder heifers. Calves were finished when the average ultrasound backfat thickness in the pen was 8–10 mm.

Final feedlot weight was the average of two weights taken on 2 consecutive days. The last weight was taken 1–3 d before slaughter. Percent shrink was calculated as the loss in live weight from final feedlot weight to slaughter weight. After a 24-h chill, carcass cooler data including grade fat thickness at the 12th rib, longissimus thoracis area, muscle score, fat class, estimated cutability, marbling score, yield grade and quality grade were recorded (Agriculture Canada 1992).

Cows that were EW and LW were sorted into nine equal weight groups of six cows per group. Additional animals (6 for EW; 13 for LW) were kept as replacements for cows culled from the study in future years. The nine groups within each weaning treatment were then randomly allocated to the following winter feeding treatments: (1) traditional, or straw fed ad libitum and barley silage fed every day (TD); (2) alternate day, or straw fed ad libitum and equivalent amounts of barley silage fed every second day (AD); and (3) swath graze, or swath grazing whole-plant barley, cut in the soft dough stage (SG). This resulted in three replicates for each production cycle by weaning treatment by winter feeding treatment ($3 \times 2 \times 3$ or 18 groups of six cows per group).

Cows in the TD and AD winter feeding treatments were housed in 12 pens from November to mid-May and had access to water from frost-free water bowls. The pens were 20% covered with an open-faced barn located over the north or prevailing wind side of the pens. The TD feeding treatment consisted of two row barley straw fed ad libitum and barley silage fed every day at 6.0–6.5 kg DM silage $head^{-1}$ d^{-1} (0.9–1.0% of body weight). It was anticipated that feeding barley silage at this level would result in a diet composition of 50% straw:50% silage on a DM basis. The AD feeding treatment consisted of two row barley straw fed ad libitum and barley silage fed on alternate days, such that the amount of silage provided to cows over the feeding period was equivalent to that provided by the TD feeding treatment. The silage was completely consumed on the day that it was fed. Straw was offered as a large round bale, in a round bale feeder situated within each pen. Grab samples of silage for quality analysis were collected weekly and pooled monthly from mid-November to the beginning of February (Table 1). Grab samples of straw for quality analysis were collected from four randomly selected pens at three or four times during each winter feeding period (Table 1).

The SG treatment consisted of AC Lacombe barley, planted in mid-June, swathed in mid-September at the soft dough stage, and grown each year in an area subdivided into six paddocks prior to grazing. A more detailed description of crop management can be obtained from Baron et al. (2002). All swath paddocks had a small open-faced shelter and were equipped with an all-weather watering system. Three groups of EW (n = 18) and three groups of LW cows (n = 18) grazed the swaths from mid-November to the beginning of February. One month prior to calving, all swath grazing cows were placed in six pens in an open-faced barn and fed according to the traditional winter feeding treatment. Barley straw bedding was provided as needed for all the winter feeding treatments. For all treatments, silage was increased after calving according to National Research Council (NRC) (1996) requirements and all cows were fed straw ad libitum. The diet composition of the winter feeding treatments during the swath grazing period (end of November to the end of February) is presented in Table 1.

All cows, whether in pens or paddocks, were maintained in their same weaning and winter-feeding treatment groups throughout the study. Cows that died or that were culled because they were open at pregnancy examination or did not wean a calf were replaced by extra cows that had been allocated to the same weaning and winter feeding treatment. In the spring, when the swath grazed fields were relatively dry, the SG cow-calf pairs were moved back onto the swath treatments to graze the swaths and clean up the residue. These nursing cows were supplemented with 2.7 kg $head^{-1}d^{-1}$ grain mix comprised of 94% steam rolled barley, 4% beef supplement (32% CP), 2% molasses and monensin sodium at 22 mg kg^{-1} (88.8% DM, 13.6% CP, 15.14 MJ DE kg^{-1} DM). Calving began in mid-March of each year. Calves were weighed within 24 h of birth, injected subcutaneously with vitamins A, D and E, castrated using rubber elastic rings and individually identified using visual plastic eartags. They were vaccinated for clostridial diseases (Blacklegol®8 with Spur, Intervet Inc., Millsboro, DE), IBR, PI3, BVD and BRSV (Triangle®4 + H.S., Fort Dodge Animal Health, Overland Park, KS) at 1–2 mo of age prior

Table 1. Composition of feeds used in cow wintering diets

	Traditional and alternate day winter feeding strategies						Swath grazing		
Components, DM basis	*n*	Barley silage	SD	*N*	Barley straw	SD	*n*	Whole plant	SD
Dry matter (%)	17	35.41	5.18	41	81.41	8.69	83	50.53	14.3
Crude protein (%)	17	11.83	1.43	41	3.13	1.07	83	12.92	5.76
Acid detergent fibre (%)	17	33.48	4.62	41	52.54	1.75	83	31.12	4.8
Neutral detergent fibre (%)	17	52.80	5.87	41	80.75	2.37	82	56.13	1.06
Total digestible nutrients[z] (%)	17	61.39	6.01	41	36.55	2.27	83	64.44	1.73
Digestible energy[y] (MJ kg^{-1})	17	11.30	1.11	41	6.73	0.42	83	11.86	5.77

[z]TDN, % = 104.96 - (1.302 × ADF, %) (Bull 1981).
[y]DE, MJ kg^{-1} DM = {(TDN,%/100) × 4.4 Mcal kg^{-1} TDN} × 4.184 MJ $Mcal^{-1}$ (NRC 1996).

to going onto perennial pasture and then given a booster just prior to late weaning in October.

Animal and Feed Measurements

Detailed data were collected over three production cycles. However, due to the overlapping nature of the production cycles, open and cull rate data were collected on four production cycles. Dam and sire breed or breed cross, dam age, dam disposal date and reason, calving ease, birth type and condition, birth weight and date and pregnancy status were recorded as part of normal herd management practice. Cows and calves were weighed and cows measured for BCS (1 = emaciated to 5 = grossly fat; Lowman et al. 1976) and ultrasound backfat thickness at early (late August) and late weaning (late October). Also, all cows were weighed on 2 consecutive days prior to morning feeding at the beginning of the winter feeding period in mid-November (1st winter feeding) and at the end of swath grazing in late February (precalving). Ultrasound backfat thickness between the 12th and 13th ribs and BCS were taken on the second weighing day at the start and end of the winter feeding period. Weight, BCS and ultrasound backfat thickness were taken again just prior to breeding when cows were scheduled to go back onto perennial pasture in late May (prebreeding).

Swathing of the individual 2.5-ha paddocks occurred when DM percentage averaged 50.5% on 197 Sep. 10, 1998 Sep. 15, and 1999 Sep. 15 (Table 1). The distance required to form a bale and the weight of the bale were recorded for calculation of dry matter yield. Baron et al. (2002) found the rate of grazing utilization in the swath was 85.4%, averaged over years and sampling periods. Five cores were removed from each bale with a power auger (Star Quality Samplers, Edmonton, AB) and the material was bulked, bagged, weighed and dried at 55°C for determination of DM concentration. Grab samples of swathed material from each replicate were sampled after swathing and then regularly throughout winter grazing. These samples were also bulked, bagged, weighed and dried for determination of DM concentration. All samples were then ground, first through a Wiley mill (Model no. 4; Arthur H. Thomas Co., Philadelphia, PA) equipped with a 1-mm screen and then though a Cyclone mill (Model MS; UD Corporation, Boulder, CO) equipped with a 0.5-mm screen. The dried ground material was used for quality analysis. Barley silage and straw for feed were weighed into each pen and straw for bedding was weighed into each pen or paddock.

The carrying capacity in cow grazing d ha^{-1} = (total cows in each paddock × total days swath grazing in each paddock)/total area grazed in each paddock. Swath consumption for each paddock in kg cow^{-1} d^{-1} = ((((bale weight, kg DM/(bale distance, m × swather width, m)) × total area grazed, m^2) × 0.854/total cows on swaths/total days on swaths). Cost of establishment of barley for swath grazing was determined by recording whole-field labour and cost inputs for cultivating, disking, fertilizer, fertilizer application, seed, seeding, harrowing, machine for spraying, chemical for spraying and swathing. The cost of barley swaths consumed in kg DM cow^{-1} d^{-1} in each paddock within year was determined by dividing the whole field cost by dry matter yield (7827, 5009, 7162 kg ha^{-1} in 1997, 1998, 1999, respectively) and multiplying by the swath utilization rate of 0.854 (Baron et al. 2002). Inputs of feed, bedding, minerals, labour and equipment for feeding and manure removal were quantified for each wintering treatment. The cost of barley silage was based on average local prices in 1997, 1998 and 1999 and was \$27 t^{-1}. Silage was bunk fed and feeding losses were negligible. Hourly ambient temperature, wind speed and precipitation were recorded from an on-site weather station.

Forage Quality

Silage, feed straw and whole-plant barley swath samples were analyzed for dry matter (DM), crude protein (CP), acid detergent fibre (ADF) and neutral detergent fibre (NDF). Dry matter was determined by drying a sample at 55°C in a forced-air oven to a constant weight. Neutral detergent fibre was determined singularly, and acid detergent fibre was determined sequentially according to Van Soest et al. (1991). Crude protein was determined using a Leco CN–2000 induction C and N analyzer (Leco Corporation, St. Joseph, MI) according to AOAC method 990.03 (AOAC 1990).

Statistical Analysis

The data were analysed using the Mixed Model Procedure (SAS Institute, Inc. 1996). Cow age, body weight, backfat thickness and BCS at early weaning were subjected to an analysis of variance. Sources of variation were production cycle (1997/1998; 1998/1999; 1999/2000), winter feeding treatment (TD, AD, SG), weaning treatment (EW, LW), pen or paddock nested within production cycle by winter feeding treatment by weaning treatment, breed cross (AnHe, ChMa), calf sex (heifer; steer) and all two- and three-way interactions between production cycle, winter feeding treatment, weaning treatment, breed cross and calf sex. Pen or paddock nested within production cycle by winter feeding treatment by weaning treatment was the error term for production cycle, winter-feeding treatment, weaning treatment and all their interaction terms. All other effects were tested against the random error term. Cow data from early weaning to prebreeding were subjected to an analysis of covariance using the same model, including cow body weight at early weaning and cow age as covariates.

Calf post-weaning performance and carcass data were subjected to an analysis of covariance. Sources of variation were production cycle (n = 3), weaning treatment (n = 2), calf sex (n = 2), pen nested within production cycle by weaning treatment by calf sex, breed cross (n=2) and all possible two-, three- and four-way interactions between production cycle, weaning treatment, calf sex and breed cross. Cow age was used as a covariate. The error term for production cycle, weaning treatment, calf sex and their interaction terms was pen nested within production cycle by weaning treatment by calf sex. All other effects were tested against the residual error term.

Calf birth date, calf birth weight, first calf born, last calf born, length of the calving span, calving interval, feed consumption and cost of production data were subjected to an analysis of variance. Sources of variation were production cycle, winter feeding treatment, weaning treatment and all possible two- and three-way interaction terms. All effects were tested against the residual error term. The variance-covariance matrix was chosen based on an iterative process wherein the best fit was based on Schwarz's Bayesian criterion. In all analysis, least squares means were separated using the PDIFF option for significant (P < 0.05) fixed effects (SAS 1996). Differences in main effects for open rate, cull rate, yield grade and quality grade data were tested using Chi square analysis (SAS Institute, Inc. 1996).

RESULTS AND DISCUSSION

Effect of Early Weaning on Calf Performance

Initially, calf age and body weight were similar (P > 0.10) for EW and LW calves, indicating a proper randomization of animals between weaning groups (Table 2). Over the next 56 d, EW calves fed a backgrounding diet (82% barley silage:18% concentrate; 12.69 MJ DE kg^{-1} DM), grew at 0.61 kg d^{-1}, which was 0.36 kg d^{-1} or 37.1% slower (P < 0.001) than calves on pasture nursing their mothers. This result was consistent across production cycles, cow breed-cross and gender of calf. Thompson et al. (2001) found that calves on range with their dams, near Kamloops, British Columbia, Canada, had ADG greater than or equal to EW calves put on irrigated pasture in 7 of 9 yr. In our study, LW calves were grazing cool season fall pastures and suckling their dams, while the EW calves were being fed a backgrounding diet formulated for an ADG of 0.68 kg d^{-1}. This rate of gain was chosen to enhance frame growth without resulting in excess fat deposition (Tatum et al. 1986). By the time LW calves were weaned at 210 d of age, they weighed 18 kg more (P < 0.001) than their EW cohorts. EW calves did not undergo compensatory gain during the 132 d backgrounding period and grew at a similar rate as LW calves. This result is indicted by the lack of relationship between early to late weaning ADG and backgrounding ADG (r = –0.068, P = 0.282). Therefore, the LW calves maintained their weight advantage of 15 kg (P < 0.01) to the start of the finishing phase (Table 2).

Table 2. Effects of time of weaning on calf performance shortly after weaning and during the backgrounding phase over 3 consecutive years

Traits	Early weaning[z]	Late weaning[z]	$P < F$
Early to late weaning (56 d)			
Number of calves[y]	162	159	
Initial age (d)	154 ± 1.2	154 ± 1.3	0.970
Initial weight (kg)	213 ± 2.2	210 ± 2.4	0.435
Age at weaning (d)	154 ± 1.2	210 ± 1.3	<0.001
ADG (kg d^{-1})	0.61 ± 0.02	0.97 ± 0.02	<0.001
Late weaning weight (kg)	247 ± 2.3	265 ± 2.5	<0.001
Backgrounding phase from late wean date			
Number of calves[x]	128	124	
Length of period (d)	131 ± 0.6	132 ± 0.7	0.183
ADG (kg d^{-1})	0.95 ± 0.01	0.93 ± 0.02	0.544
End weight (kg)	372 ± 3.5	387 ± 4.2	0.007

[z]Values shown are least squares means ± SE.
[y]Number of calves are less than expected (EW = 162; LW = 162) due to death losses (LW = 3).
[x]Number of calves are less due to replacement heifer selection (EW = 33; LW = 34) and death losses (EW = 1; LW = 1).

No differences were observed between EW and LW calves in finishing performance, days on the finishing diet, age and weight at slaughter, percent shrink, carcass weight, grade fat, l. thoracis area, lean meat yield and yield grade (Table 3). Most quality grades were similar between EW and LW calves, though the percentage of AA carcasses tended (P = 0.08) to be higher in EW calves than LW calves. The reason for this small difference is uncertain especially when all other performance and carcass measurements between EW and LW calves were similar. Thus, while EW calves did eventually catch up to LW calves at finishing, they also incurred $44.75 in extra feeding costs (average cost of gain = $1.37 kg^{-1} gain; ADG = 0.61 kg d^{-1} over 56 d; Canfax Trends West; January–December 1998; http://www.canfax.ca/) due to being in drylot on stored feed for 56 d longer than LW calves. However, the cost of LW calves being on their dams was estimated at $23.34 per calf. This value was calculated using the following assumptions: (i) one animal unit (AU) is defined as a 454 kg cow with calf under 60 d of age; (ii) LW calves midpoint weight from early to late weaning was 237 kg or 0.52 AU; (iii) the cost of an animal unit month was $24; (iv) the cost of LW calves on pasture with their dams from early to late weaning (56 d) was calculated by multiplying 0.52 AU by 1.87 mo of extra pasture for LW calves by $24 AUM^{-1}. Thus the extra costs associated with early weaning were $21.41 per calf. This result again stresses that early-weaned calves need to grow at a rate at least similar to or greater than that achieved on the cow to be cost effective.

Effect of Early Weaning on Cow Growth Performance

Cow age, weight, backfat thickness and BCS were similar (P > 0.10) between EW and LW cows at early weaning each year

Table 3. Effects of time of weaning on calf growth traits during the finishing phase and on carcass traits over 3 consecutive years

Traits	Early weaning	Late weaning	$P < F$
Number of calves^z	128	124	
Finishing phase^y			
Start age (d)	341 ± 1.7	343 ± 2.0	0.479
ADG (kg d^{-1})	1.56 ± 0.04	1.53 ± 0.05	0.620
Days on feed (d)	121 ± 4.3	112 ± 5.1	0.168
Final backfat thickness (mm)	9.8 ± 0.4	9.7 ± 0.5	0.821
Final weight (kg)	554 ± 5.2	548 ± 6.2	0.460
Slaughter age (d)	461 ± 4.2	455 ± 5.0	0.326
Slaughter weight (kg)	522 ± 4.8	515 ± 5.8	0.390
Shrink (%)	5.8 ± 0.2	5.9 ± 0.3	0.733
Total time on feed (d)	310 ± 4.3	245 ± 5.0	<0.001
Carcass traits^y			
Cold carcass weight (kg)	313.4 ± 3.0	309.4 ± 3.6	0.388
Grade fat (mm)	10.5 ± 0.5	10.0 ± 0.5	0.503
Longissimus thoracis area (cm^2)	81.6 ± 1.1	81.1 ± 1.4	0.798
Lean meat yield (%)	58.6 ± 0.4	59.0 ± 0.5	0.565
Carcass yield and quality grade			
Yield Grade; Y1 (%)	37.5	37.9	0.908
Y2 (%)	39.8	37.9	0.732
Y3 (%)	22.7	24.2	0.793
Quality Grade; A (%)	12.5	12.1	0.864
AA (%)	71.1	62.1	0.076
AAA (%)	14.8	21.0	0.147
B1 (%)	0.8	2.4	0.176
B4 (%)	0.8	2.4	0.176

^{z}Number of calves are less than expected (EW = 162; LW = 162) due to replacement heifer selection (EW = 33; LW = 34) and death losses (EW = 1; LW = 4).
^{y}Values shown are least squares means ± SE.

Table 4. Effects of time of weaning on cow performance over 3 production cycles.

Traits	Early weaning^z	Late weaning^z	$P < F$
Number of animals	162	162	
Initial traits at early weaning (Aug. 26–27)			
Cow age (yr)	5.2 ± 0.2	5.3 ± 0.2	0.579
Cow weight (kg)	673 ± 5.2	667 ± 5.3	0.416
Cow backfat thickness (mm)	7.5 ± 0.3	7.6 ± 0.3	0.917
Cow body condition score^y	3.2 ± 0.05	3.3 ± 0.05	0.361
Average daily gain (kg d^{-1})			
Early to late weaning (56 d)	0.16 ± 0.03	0.07 ± 0.03	0.017
Late wean–1st winter feed (28 d)	0.34 ± 0.05	–0.15 ± 0.05	<0.001
1st winter feed-precalving (78 d)	0.27 ± 0.02	0.30 ± 0.02	0.346
Precalving -prebreeding (105 d)	–0.84 ± 0.04	–0.85 ± 0.04	0.853
Prebreeding-early wean (267 d)	–0.06 ± 0.004	–0.08 ± 0.004	0.001
Weight (kg)			
Late weaning (Oct. 21–22)	675 ± 1.4	670 ± 1.5	0.017
1st winter feeding (Nov. 8–19)	682 ± 1.4	667 ± 1.4	<0.001
Precalving (Feb. 5-Mar 1)	705 ± 2.5	692 ± 2.5	0.001
Prebreeding (May 19–23)	629 ± 2.5	616 ± 2.6	0.001
Back fat thickness (mm)			
Late weaning	8.6 ± 0.4	8.1 ± 0.4	0.409
1st winter feeding	8.2 ± 0.3	7.4 ± 0.3	0.097
Precalving	7.2 ± 0.3	6.8 ± 0.3	0.385
Prebreeding	5.6 ± 0.3	5.1 ± 0.3	0.248
Body condition score^z			
Late weaning	3.2 ± 0.05	3.1 ± 0.06	0.208
1st winter feeding	3.2 ± 0.05	3.1 ± 0.05	0.153
Precalving	2.9 ± 0.05	2.9 ± 0.05	0.649
Prebreeding	2.9 ± 0.05	2.8 ± 0.05	0.156

^{z}Values shown are least squares means ± SE.
^{y}Body condition score was based on the Scottish system (Lowman et al. 1976) and was scored from 1 (emaciated) to 5 (grossly fat).

(Table 4). EW cows gained 5.0 kg (0.09 kg d^{-1}) more over the 56-d period than LW cows that were still nursing their calves. Similar results were reported in another Canadian study where dry cows gained 9.6 kg over the 55-d period compared to the late weaned cows that lost 8.4 kg over the same period (Thompson et al. 2001). In our study, EW cows continued to gain weight at 0.34 kg d^{-1} from late weaning to the beginning of the winter feeding period, while LW cows lost 0.15 kg d^{-1}. Both EW and LW cows gained or lost weight similarly from the start of winter feeding to precalving and from precalving to prebreeding. Cow body weight differences that resulted from the weaning treatment were maintained throughout the winter feeding, precalving and prebreeding periods, such that EW cows weighed 15 kg more ($P < 0.001$) than LW cows at the beginning of winter feeding, 13 kg more ($P < 0.001$) at precalving and 13 kg more ($P < 0.001$) at prebreeding. This difference in body weight observed between EW and LW cows was maintained over the next two productions cycles as indicated by the non-significant ($P > 0.10$) production cycle by weaning treatment interaction for cow weight at these various time periods. The body weight differences caused by early weaning were also reflected in EW cows having slightly more backfat than LW cows at the beginning of winter feeding in each year (8.5 vs. 7.6 in 1997; 8.1 vs. 7.3 in 1998; 8.0 vs. 7.3 in 1999; $P = 0.098$). Most results were consistent across production cycles, winter feeding treatments, cow breed groups and gender of calf. A notable exception was a significant ($P < 0.001$) weaning treatment by breed-cross interaction in cow's ADG from late weaning to first winter feeding (28 d). LW AnHe cows (659 ± 1.4 kg) gained 0.22 ± 0.07 kg d^{-1}, while LW ChMa cows (687 ± 1.9 kg) lost 0.52 ± 0.08 kg d^{-1}. Both EW AnHe cows and EW ChMa cows gained weight (0.40 ± 0.06 vs. 0.28 ± 0.06 kg d^{-1}). These results indicate that LW large sized ChMa cows were more adversely affected by late weaning than moderate sized AnHe cows.

Effect of Early Weaning on Cow Reproductive Performance

The subsequent year's calf birth date and weight, date of first calf born, date of last calf born, calving interval, and calving pattern were similar between EW and LW cows (Table 5). However, EW cows had a calving span that was 13 d shorter ($P = 0.07$) than the calving span of LW cows, thus giving an indication that early weaning may be having a positive effect on cow reproductive performance. However, cumulative cull and open rates were similar for EW and LW cows monitored over four production cycles, such that 41–44% of the initial cows in both weaning groups were culled after 4 yr (Table 6). A possible reason why weaning treatment had no effect on cow reproductive performance was that both EW and LW cows were in fair to good BCS (2.5 to 3.5) throughout the study period. Negative effects on cow reproduction occur when BCS drops below 2.5, particularly during the precalving and prebreeding periods (Selk et al. 1988).

Effect of Early Weaning on Labour and Cash Costs

Early weaning of cows had no effect on consumption of silage and straw during the winter feeding period, labour required for feeding, bedding and manure removal, or on costs of labour and feed (Table 7). Since both EW and LW cows were in similar BCS at the beginning of the winter feeding period (EW = 3.2; LW = 3.1; P = 0.15), no adjustment was made to the feed required by each weaning group to maintain their BCS. If the difference was more severe, say one BCS score, then the winter diet would have been changed to improve the BCS. Koberstein et al. (2001) have shown that under Alberta conditions, one BCS on a cow going into winter can mean an extra cost or saving of $35–60 per cow, depending on feed cost and cow size.

Effect of Winter Feeding Strategies on Cow Growth Performance

In 1997, at early weaning, cows in each winter feeding treatment group were similar in body weight (TD = 653 kg, SG = 646 kg, AD = 647 kg, SEM = 12 kg, P = 0.916), age (TD = 4.3 yr, SG = 3.9 yr, AD = 4.2 yr, SEM = 0.4 yr, P = 0.722) and backfat thickness (TD = 6.9 mm, SG = 8.2 mm, AD = 7.9 mm, SEM = 0.7 mm, P = 0.436). This result was consistent across production cycles since winter feeding groups were similar in age, weight, backfat thickness and BCS at early weaning (Table 8) and no significant (P > 0.10) production cycle by winter feeding treatment interactions were observed for these same traits. Cows in the TD, SG and AD winter feeding groups continued to be similar in ADG, body weight, backfat thickness and BCS from early weaning to the start of the winter feeding period in each production cycle (Table 8). Again, this result was confirmed by the non-significant production cycle by winter feeding treatment interactions for these traits from early weaning to the start of winter feeding. Thus, any differences that occurred among the winter feeding groups from the start of swath grazing to prebreeding were negated during the following summer's grazing season.

Cows grazing swaths (SG) gained weight more slowly from the start of winter feeding (mid-November; 5–6 mo pregnant) to precalving (February; 1–4 wk before calving) than cows under a TD or AD winter feeding program (0.04 vs. 0.42 vs. 0.39 kg d^{-1} respectively; P < 0.001; Table 8). Traditional fed and SG cows lost weight (–0.75 and –0.81 kg d^{-1}) at a similar rate between precalving and prebreeding, but lost less weight than cows on the AD feeding strategy (–0.97 kg d^{-1}). Thus, cow weight at prebreeding was lowest for SG as compared to AD and TD cows. Much of the loss in weight that occurred in all groups between precalving and prebreeding is a reflection of the loss in foetal weight, and placental and foetal membranes and fluids. This weight loss had no negative impact on cows as all were in BCS 2.5 to 3.5. These results were consistent across production cycle, weaning treatment and cow breed cross.

Table 5. Effects of time of weaning on subsequent cow reproductive performance over 3 production cycles

Traits	Early weaning	Late weaning	$P < F$
Number of groups	9	9	
Subsequent year traits[z]			
Calf birth date (Julian date)	87 ± 1	86 ± 1	0.406
Calf birth weight (kg)	44.6 ± 0.6	45.3 ± 0.6	0.399
First calf born (Julian date)	67 ± 5	58 ± 5	0.250
Last calf born (Julian date)	111 ± 10	131 ± 10	0.228
Length of the calving span (d)	49 ± 3.7	62 ± 3.7	0.073
Calving interval (d)	368 ± 1	365 ± 1	0.284
Calving Pattern (% of total)			
1 to 21 d	32.1	36.0	0.456
22 to 42 d	47.4	44.1	0.551
43 to 63 d	19.9	17.4	0.571
64 to 84 d	0.6	1.9	0.330
85 to 105 d	0.0	0.6	0.320

[z]Values shown under time of weaning treatments are least squares means ± SE.

Table 6. Effect of time of weaning on cumulative cull and open rates for cows initially placed on study during the 1996/1997 production cycle

Traits	Early weaning	Late weaning	Prob. level
Initial number of cows	54	54	
Open rate (%)			
Production cycle 1997/1998	0.0	0.0	1.000
1998/1999	13.0	13.0	1.000
1999/2000	18.5	13.0	0.428
2000/2001	35.2	31.5	0.683
Cull rate (%)			
Production cycle 1997/1998	0.0	3.7	0.153
1998/1999	13.0	18.5	0.428
1999/2000	22.2	24.1	0.820
2000/2001	40.7	44.4	0.697

Effect of Winter Feeding Strategies on Cow Reproductive Performance

Winter feeding strategies were similar for the subsequent year's calf birth date and weight, date of first calf, date of last calf, calving span, calving interval and calving pattern (Table 9). In addition, cumulative open or cull rates were similar for cows in the three winter feeding groups (P > 0.10) for cows monitored over four production cycles (Table 10). By the end of the fourth year 42–44% of the original cows from each winter feeding group had been culled.

Effect of Winter Feeding Strategies on Feed Consumption.

SG cows consumed swaths at a rate of 10.9 kg DM d^{-1}, which was similar (P > 0.10) to the silage and straw DM consumed by TD and AD cows (Table 11). However, SG cows consumed 17.5 and 21.2% more digestible energy than TD and AD cows, respectively. Despite consuming more energy, SG cows gained less weight (0.04 vs. 0.42 vs. 0.39 kg d^{-1} for SG, TD, AD respectively) during the swath grazing period than either traditional fed or alternate day fed cows (Table 8).

Table 7. Labour and cash costs for early and late weaned cows from first winter feeding to pre-calving on a pen basis over three production cycles

Items	Early weaned[z]	Late weaned[z]	$P < F$
Number of observations	27	27	
Feed consumption (kg DM cow^{-1} d^{-1})			
Silage	7.89 ± 0.25	7.55 ± 0.25	0.348
Straw	3.58 ± 0.14	3.54 ± 0.14	0.833
Total	11.47 ± 0.28	11.09 ± 0.28	0.355
Energy consumed (MJ DE cow^{-1} d^{-1})	113 ± 23.0	109.0 ± 3.0	0.337
Labour[z] (min cow^{-1} d^{-1})			
Feeding[y]	0.505 ± 0.002	0.505 ± 0.002	0.962
Bedding	0.179	0.179	
Manure removal	0.251	0.251	
Total	0.935 ± 0.002	0.935 ± 0.002	0.962
Labour costs[z] ($ cow^{-1} d^{-1})			
Feeding[x]	0.123 ± 0.001	0.123 ± 0.001	0.963
Labour for bedding	0.044	0.044	
Labour for manure removal	0.062	0.062	
Total	0.229 ± 0.001	0.229 ± 0.001	0.963
Feed cost[y] ($ cow^{-1} d^{-1})			
Feed[y]	0.582 ± 0.008	0.574 ± 0.008	0.495
Bedding	0.172	0.172	
Minerals	0.038	0.038	
Salt blocks	0.018	0.018	
Total	0.810 ± 0.008	0.802 ± 0.008	0.495
Other costs ($ cow^{-1} d^{-1})			
Equipment for feeding	0.080	0.080	
Equipment for manure removal[w]	0.145	0.145	
Total cost ($ cow^{-1} d^{-1})	1.264 ± 0.009	1.256 ± 0.009	0.502

[z]Where possible, values shown are least squares means ± SE.
[y]Winter feeding required labour for feeding straw, silage, manure removal (two men × 16 h) and moving fences ($14.66 h^{-1}), all cattle were fed and bedded similarly.
[x]Winter feeding included the cost of silage ($27 t^{-1} or $0.0718 kg^{-1} DM in 1997, 37.6% DM; $0.0754 kg^{-1} DM in 1998, 35.8% DM; $0.0860 kg^{-1} DM in 1999, 31.4% DM) and straw ($33.35 t^{-1}, 89.9% DM). The cost of swath grazed forage was $206.95 ha^{-1} and included cultivating ($13.59 ha^{-1}), disking ($17.30 ha^{-1}), fertilizer ($98.84 ha^{-1}), fertilizer application ($9.88 ha^{-1}), seed ($18.53 ha^{-1}), seeding ($12.36 ha^{-1}), harrowing ($6.18 ha^{-1}), machine for spraying ($7.41 ha^{-1}), chemical ($8.03 ha^{-1}) and swathing ($14.83 ha^{-1}). Cost per kilogram was determined by dividing $206.95 by DM yield of each paddock by utilization rate (0.846; Baron et al. 2002). Bedding straw was $1.45 per small square bale and $14.50 per large round bale. Mineral was $16.85 per 25 kg bag and salt was $5 per block.
[w]Manure was removed once from all treatment pens and required 16 h of equipment time ($69.68 h^{-1}).

These results indicated that cows grazing swaths required at least 18 to 21% extra energy, possibly to offset the energy costs of walking, foraging and maintaining body temperature during winter. NRC (1996) states that maintenance energy requirements increase by 10–20% for grazing as compared to penned cattle. In addition, SG cows were more exposed to wind during winter grazing as compared to TD and AD cows that were in sheltered pens. Average wind speed from November to February for cows grazing swaths was 8.0, 9.7 and 7.9 km h^{-1} for the 1997/1998, 1998/1999 and 1999/2000 swath grazing periods.

The actual ADF of the whole-plant swathed barley monitored during December, January and February over the three swath grazing periods was 31.12% (Table 1), thus giving a swath energy content of 11.86 MJ DE kg^{-1} DM. Predicted ADG for a 676 kg cow in BCS 3.0 consuming 10.94 kg DM and 7.5 mo pregnant (ambient temperature = –7.5°C; previous month's temperature = –6.0°C; wind speed = 9 km h^{-1}) was 0.10 kg d^{-1} (NRC 1996). This was similar to the actual ADG of 0.04 kg d^{-1} for cows consuming barley swaths averaged over the three winter grazing periods. Only limited snow fell throughout the three wintering periods (4.1, 7.7 and 4.1 cm from Nov. 01 to Feb. 01 for 1997/1998, 1998/1999 and 1999/2000, respectively) and few days were below –20°C (14 d in Jan. 1998; 9 d in Jan. 1999; 5 d in Jan. 2000). Average ambient temperature from November to February was –7.0, –8.8 and –6.9°C for the 1997/1998, 1998/1999 and 1999/2000 swath grazing periods. Thus, cows grazing barley swaths under mild winter conditions performed as predicted by NRC (1996). However, cows fed silage and free choice straw consumed 15.8% to 20.1% less DM and achieved gains that were higher than predicted by NRC (1996). This was most likely caused by NRC (1996) overestimating the actual energy requirements of the cows fed the silage and straw diet to maintain body weight.

Effect of Winter Feeding Strategies on Economic Performance

The labour and cash costs associated with the different winter feeding strategies are outlined in Table 11. Swath graz-

Table 8. Effects of winter feeding strategy on cow growth performance over three production cycles

Traits	Traditional feeding[z]	Swath grazing[z]	Alternate day feeding[z]	P < F
Number of animals	108	106	108	
Initial traits at early weaning				
Age (yr)	5.4 ± 0.2	4.9 ± 0.2	5.4 ± 0.2	0.241
Weight (kg)	673 ± 6.2	670 ± 6.4	667 ± 6.6	0.772
Backfat thickness (mm)	7.6 ± 0.4	8.0 ± 0.4	6.9 ± 0.4	0.184
Cow body condition (scale1–5)	3.2 ± 0.1	3.3 ± 0.1	3.2 ± 0.1	0.461
Average daily gain (kg d^{-1})				
Early to late weaning (56 d)	0.07 ± 0.03	0.14 ± 0.03	0.15 ± 0.03	0.175
Late wean — 1st winter feed (28 d)	0.05 ± 0.06	0.07 ± 0.06	0.16 ± 0.07	0.437
1st winter feed — precalving (78 d)	0.42 ± 0.03*a*	0.04 ± 0.03*b*	0.39 ± 0.03*a*	<0.001
precalving — prebreeding (105 d)	–0.75 ± 0.04*b*	–0.81 ± 0.04*b*	–0.97 ± 0.05*a*	0.003
Weight (kg)				
Late weaning (Oct. 21–22)	670 ± 1.7	673 ± 1.8	674 ± 1.8	0.176
1st Winter feeding (Nov. 8–19)	672 ± 1.7	676 ± 1.7	677 ± 1.8	0.121
Precalving (Feb. 5-Mar. 1)	709 ± 3.0*a*	676 ± 3.1*b*	711 ± 3.2*a*	<0.001
Prebreeding (May 19–23)	639 ± 3.1*a*	605 ± 3.1*c*	623 ± 3.2*b*	<0.001
Backfat thickness (mm)				
Late weaning	8.6 ± 0.5	9.2 ± 0.5	7.3 ± 0.5	0.052
1st winter feeding	7.9 ± 0.4	8.3 ± 0.4	7.2 ± 0.4	0.130
Precalving	7.5 ± 0.4	6.8 ± 0.4	6.7 ± 0.4	0.314
Prebreeding	6.4 ± 0.4*a*	4.5 ± 0.4*b*	5.1 ± 0.4*b*	0.004
Body condition score[y]				
Late weaning	3.1 ± 0.1	3.3 ± 0.1	3.1 ± 0.1	0.145
1st winter feeding	3.0 ± 0.1*b*	3.3 ± 0.1*a*	3.2 ± 0.1*ab*	0.004
Precalving	2.9 ± 0.1	2.8 ± 0.1	2.9 ± 0.1	0.341
Prebreeding	3.0 ± 0.1*a*	2.9 ± 0.1*ab*	2.7 ± 0.1*b*	0.012

[z]Values shown are least squares means ± SE.
[y]Body condition score was based on the Scottish system (Lowman et al. 1976) and was scored from 1 (emaciated) to 5 (grossly fat).
a–c Least squares means within a row and with different letters differ ($P < 0.05$).

Table 9. Effects of winter feeding strategy on subsequent cow reproductive performance over three production cycles

Traits	Traditional feeding	Swath grazing	Alternate day feeding	P < F
Number of observations	9	9	9	
Subsequent year traits[z]				
Calf birth date (Julian date)	87 ± 1	86 ± 1	86 ± 1	0.907
Calf birth weight (kg)	45.6 ± 0.7	45.6 ± 0.7	43.7 ± 0.7	0.171
First calf born (Julian date)	60 ± 4	64 ± 4	66 ± 4	0.565
Last calf born (Julian date)	120 ± 11	118 ± 11	121 ± 11	0.982
Length of the calving span (d)	56 ± 4.5	56 ± 4.5	56 ± 4.5	0.998
Calving interval (d)	368 ± 2	365 ± 2	367 ± 2	0.385
Calving pattern (% of total)				
1 to 21 d	31.4	38.7	32.1	0.469
22 to 42 d	51.4	38.7	47.1	0.167
43 to 63 d	16.2	20.7	18.9	0.693
64 to 84 d	0.0	1.9	1.9	0.367
85 to 105 d	1.0	0.0	0.0	0.363

[z]Values shown under time of weaning treatments are least squares means ± SE.

ing required 38.4% less labour than traditional feeding and 20.9% less labour than alternate day winter feeding of the energy supplement during the first 100 d of winter feeding (72.3 vs. 117.4 vs. 91.4 min cow^{-1}, respectively). Alternate day feeding required 22.1% less labour than traditional winter feeding during this same period. Labour for bedding and the amount of bedding straw used in the swath grazing treatment was greater than for the other treatments, but this was caused by the difference of bedding small experimental feedlot pens versus establishing a bedding pack in a field. In our study, these differences resulted in total labour costs of \$17.60, \$28.60 and \$22.20 cow^{-1} for the first 100 d of winter feeding for the SG, TD and AD winter feeding strategies, respectively.

Table 10. Effect of feeding treatment on cumulative cull and open rates for cows initially placed on study during the 1996/1997 production cycle

Traits	Traditional feeding	Swath grazing	Alternate day feeding	Probability level
Initial number of cows	36	36	36	
Open rate (%)				
Production cycle 1997/1998	0	0	0	1.000
1998/1999	13.9	16.7	5.6	0.321
1999/2000	19.4	16.7	5.6	0.197
2000/2001	36.1	27.8	30.6	0.883
Cull rate (%)				
Production cycle 1997/1998	0	5.6	0	0.130
1998/1999	13.9	22.2	11.1	0.404
1999/2000	25	27.8	16.7	0.508
2000/2001	44.4	41.7	41.7	0.963

Table 11. Labour and cash costs of various winter feeding strategies for spring calving cows from first winter feeding to pre-calving on a pen basis over three production cycles

Items	Traditional Feeding[z]	Swath Grazing[z]	Alternate Day[z]	$P < F$
Number of observations	18	18	18	
Feed consumption (kg DM cow^{-1} d^{-1})				
Silage or swath	6.19 ± 0.30*b*	10.94 ± 0.30*a*	6.03 ± 0.32*b*	<0.001
Straw	5.55 ± 0.17*a*	0.00 ± 0.17*b*	5.13 ± 0.18*a*	<0.001
Total	11.74 ± 0.34	10.94 ± 0.34	11.16 ± 0.36	0.234
Energy consumed (MJ DE cow^{-1} d^{-1})	105.2 ± 3.6*b*	127.5 ± 3.6*b*	100.5 ± 3.9*a*	<0.001
Labour (min cow^{-1} d^{-1})				
Feeding[y]	0.695 ± 0.003*a*	0.386 ± 0.003*c*	0.435 ± 0.003*b*	<0.001
Bedding[y]	0.137 ± 0.001*b*	0.268 ± 0.001*a*	0.136 ± 0.001*b*	<0.001
Manure removal/spreading[y]	0.342 ± 0.001*a*	0.069 ± 0.001*b*	0.343 ± 0.001*a*	<0.001
Total	1.174 ± 0.003*a*	0.723 ± 0.003c	0.914 ± 0.003*b*	<0.001
Labour costs ($ cow^{-1} d^{-1})				
Feeding[x]	0.170 ± 0.001*a*	0.094 ± 0.001*c*	0.106 ± 0.001*b*	<0.001
Labour for bedding[x]	0.033 ± 0.001*b*	0.065 ± 0.001*a*	0.033 ± 0.001*b*	<0.001
Labour, manure removal/spreading[x]	0.083 ± 0.001*a*	0.017 ± 0.001*b*	0.083 ± 0.001*a*	<0.001
Total	0.286 ± 0.001*a*	0.176 ± 0.001*c*	0.222 ± 0.001*b*	<0.001
Feed cost[y] ($ cow^{-1} d^{-1})				
Feed	0.689 ± 0.010*a*	0.385 ± 0.010*c*	0.660 ± 0.011*b*	<0.001
Bedding	0.162 ± 0.001*b*	0.192 ± 0.001*a*	0.162 ± 0.001*b*	<0.001
Minerals	0.039 ± 0.001*a*	0.035 ± 0.001*b*	0.040 ± 0.001*a*	<0.001
Salt blocks	0.021 ± 0.001*a*	0.012 ± 0.001*b*	0.021 ± 0.001*a*	<0.001
Total	0.911 ± 0.010*a*	0.624 ± 0.010*a*	0.883 ± 0.010*b*	<0.001
Other costs ($ cow^{-1} d^{-})^{1}				
Equipment for feeding	0.141 ± 0.001*a*	0.000 ± 0.001*c*	0.100 ± 0.001*b*	<0.001
Equip., manure removal/spreading[w]	0.199 ± 0.001*a*	0.037 ± 0.001*b*	0.199 ± 0.001*a*	<0.001
Total costs ($ cow^{-1} d^{-1})	1.537 ± 0.010*a*	0.837 ± 0.010*c*	1.404 ± 0.011*b*	<0.001

[z]Values shown are least squares means ± SE.
[y]Traditional and alternate day winter feeding required labour ($14.66 h^{-1}) for feeding, bedding and manure removal while swath grazing requires labour for moving fences, bedding and spreading the bedding mound .
[x]Traditional and alternate day winter feeding included the cost of silage ($27 t^{-1} based on Canfax market reports for the period: $0.0718 kg^{-1} DM in 1997, 37.6% DM; $0.0754 kg^{-1} DM in 1998, 35.8% DM; $0.0860 kg^{-1} DM in 1999, 31.4% DM) and straw ($33.35 t^{-1}, 89.9% DM). The cost to establish swath grazed forage was $206.95 ha^{-1} and included cultivating ($13.59 ha^{-1}), disking ($17.30 ha^{-1}), fertilizer ($98.84 ha^{-1}), fertilizer application ($9.88 ha^{-1}), seed ($18.53 ha^{-1}), seeding ($12.36 ha^{-1}), harrowing ($6.18 ha^{-1}), machine for spraying ($7.41 ha^{-1}), chemical ($8.03 ha^{-1}) and swathing ($14.83 ha^{-1}). Cost per kilogram was determined by dividing $206.95 by DM yield of each paddock by utilization rate (0.846; Baron et al. 2002). Bedding straw was $1.45 per small square bale and $14.50 per large round bale. Mineral was $16.85 per 25 kg bag and salt was $5 per block.
[w] Manure was removed from all drylot pens once per year at an equipment cost of $69.68 h^{-1}. The bedding mound in each swath grazing paddock was spread once per year at an equipment cost of $69.68 h^{-1}.
a–c Least squares means within a row and with different letters differ ($P < 0.05$).

The cost of feed, bedding, minerals and salt blocks was $62.40, $91.10 and $88.30 cow^{-1} for the first 100 d of winter feeding for the SG, TD and AD winter feeding strategies, respectively (Table 11). With the addition of the labour and equipment costs for feeding, bedding and manure removal, the total cash costs for 100 d of winter feeding were $83.70,

\$153.70 and \$140.40 cow^{-1} for SG, TD and AD feeding strategies. Thus, over a 100-d period, SG cost \$70.00 cow^{-1} less than TD (45.5%) and \$56.70 cow^{-1} (40.4%) less than AD feeding. AD feeding cost \$13.30 cow^{-1} (8.6%) less for 100 d than TD. As these costs reflect small paddock and pen costs under research conditions, a survey of 31 Alberta cow-calf producers in 2000–2001 revealed that the total cost of SG, TD and AD feeding strategies were \$0.61, \$1.14 and \$1.12 cow^{-1} d^{-1}, respectively (Kaliel and Kotowich 2002). Thus, the proportional differences between traditional and swath grazing wintering systems as determined by our study and the survey were similar at 45.5 and 46.5%. This was not the case for the proportional difference in the cost of winter feeding for the TD and AD feeding systems in our study (8.6%) and in the survey (1.8%). In our study, labour was based on one feeding trip every other day, while in the Alberta survey two feeding trips were required. Thus, a feeding strategy of 100 d of swath grazing has the potential of saving between \$53.00 (Kaliel and Kotowich 2002) and \$70.00 cow^{-1} wintered or approximately \$66.8 to 88.2 million annually for the 1.26 million beef cows estimated to inhabit central and northern Alberta.

In 1997, cows were able to swath graze from Nov. 19 to Jan. 30 [70 d; 735 (SD = 206) cow grazing d ha^{-1}], with snow arriving the first week in January. In 1998, cows grazed from Dec. 01 to Feb. 17 [79 d; 412 (SD = 46) cow grazing d ha^{-1}] with snow on the ground throughout the trial and as deep as 8 cm. Snow arrived in early January in the last year and cows were able to graze from 1999 Nov. 08 to 2000 Mar. 02 [115 d; 727 (SD = 337) cow grazing d ha^{-1}]. The carrying capacity averaged 609 cow grazing d ha^{-1} over the three swath grazing periods. The cost of swaths was \$206.95 ha^{-1}, while feed for TD and AD winter feeding strategies cost \$0.689 and \$0.660 cow^{-1} d^{-1}, respectively (Table 11). Thus, 300 and 314 cow swath grazing d ha^{-1} (206.95/0.689) was needed to break even or to cover the costs of feed in the TD and AD winter feeding strategies, respectively. Stated alternatively, 50 and 52 d of swath grazing are required to break even on feed costs in the TD and AD winter feeding strategies if stocking at 6 cows ha^{-1}.

CONCLUSIONS

Early-weaned calves on a backgrounding diet grew slower than calves still on pasture with their dams, and early- and late-weaned calves grew at the same rate during the finishing period. While early- and late-weaned calves were similar in carcass traits, early-weaned calves required 56 more days on feed to obtain the same level of finish. These results showed that if calves are early weaned, they must obtain growth rates superior to their gains on pasture. Cows that were early weaned were 13 kg heavier than late-weaned cows at prebreeding time the next year. This had a positive impact on length of the calving span.

Swath-grazed cows lost more weight over the winter feeding period than cows fed either traditionally or on alternate days. This had no effect on the reproductive performance of the swath grazed cows and all cows were in similar body condition (2.5–3.0). Considerable labour and cost savings were obtained from swath grazing and alternate day feeding of the energy supplement. Thus, the adoption of swath grazing and/or alternate day winter feeding strategies would result in large improvements in production efficiency and global competitiveness for cow-calf managers in the central and northern Aspen Parkland of Western Canada.

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