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Milk yield of primiparous beef cows from three calving systems and varied weaning ages

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ABSTRACT: Primiparous beef cows produced in 3 calving systems were used in a 2-yr study with a completely random design to measure milk yield throughout a 190-d lactation (2002, n = 20; 2003, n = 24 per calving system). Calving occurred in late winter (average calving date = February 4 ± 2 d), early spring (average calving date = March 30 ± 2 d), and late spring (average calving date = May 26 ± 1 d). Additionally, cows used in this study had been weaned at varied ages as calves, creating 6 dam treatments. Dam age at weaning was 140 (late spring), 190 (late winter, early spring, late spring), or 240 (late winter, early spring) d of age. Milk production was measured by using the weigh-suckle-weigh technique at an average of 20, 38, 55, 88, 125, 163, and 190 d in milk. Milk yield for the 190-d lactation period was calculated as area under the curve by trapezoidal summation. Data were analyzed with a model containing treatment, year, and their interaction. Orthogonal contrasts were used to separate effects when treatment was significant ($P < 0.10$). Total milk yield did not differ ($P = 0.42$) between cows in the late winter and early spring systems, but cows in the late spring system tended to differ ($P = 0.09$) from the average of the other 2 systems. Cows in the late spring calving system had increased milk yield in 2002 and lesser milk yield in 2003 compared with the other calving systems (treatment × year interaction, $P < 0.001$). Cows born in late spring that had been weaned at 140 d of age produced more ($P = 0.05$) total milk than those weaned at 190 d of age. Peak milk yield was affected ($P < 0.001$) by treatment and showed a treatment × year interaction ($P = 0.006$). Day of peak lactation differed among treatments ($P = 0.002$), with cows in the late winter system peaking later ($P = 0.007$) than early spring cows, and late spring cows peaking earlier ($P = 0.004$) than the average of late winter and early spring cows. The average date of peak lactation was May 4 for the late winter system, May 31 for the early spring system, and July 19 for the late spring system. Calf ADG differed ($P < 0.001$) for the late spring system compared with the average of the late winter and early spring systems, but the relationship interacted with year ($P < 0.001$). Cow BW and BW change differed among treatments ($P < 0.004$), with much of the difference associated with the amount of milk produced or the timing of peak lactation. Season of calving affects milk yield of primiparous cows grazing Northern Great Plains rangelands and ADG of their calves.

Key words: beef cow, calving date, milk yield, rangeland

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INTRODUCTION

Milk yield of the dam is a major determinant of growth rate in beef calves (Totusek et al., 1973). Forage quality within rangeland systems can affect growth rate of calves through influences on the milk yield of dams and quality of the forage portion of a calf's diet (Grings et al., 1996). Adjusting calving time for beef cows from late winter through late spring affects the quality of forage available for milk production and the growth of calves in the Northern Great Plains. Several authors have reported a decline in lactation persistency with poorer nutrition in beef cows (Jenkins and Ferrell, 1984; Arthur et al., 1997). Systems leading to decreased milk yield throughout lactation are expected to result in decreased calf gains for that system, especially where forage quality or quantity may be limiting to calf growth. Calves suckling dams with lowered milk yield tend to eat more forage to compensate (Baker et al.,

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1976; Ansotegui et al., 1991). However, Holloway et al. (1982) suggested that this occurs only under conditions of high forage quality, perhaps because of physical constraints on intake with forages of lower quality. Previous research at this location has shown decreased weaning weights in calves from a late spring calving system compared with late winter and early spring systems (Grings et al., 2005). Prepubertal rate of gain has been suggested to be a factor in milk yield of cows (Buskirk et al., 1996; Sejrsen et al., 2000). Both calving system and age of weaning affect ADG from birth to weaning and could have carryover effects on milk yield in beef cows raised in differing systems. The current study evaluated milk yield, BW, and BCS changes of primiparous cows born and raised within 3 calving systems and weaned at 2 ages as calves and the impact of these factors on subsequent growth of their calves.

MATERIALS AND METHODS

All animal procedures were approved by the USDA-ARS, Miles City Institutional Animal Care and Use Committee.

In a 2-yr study, primiparous cows from 3 calving systems were used to study milk yield throughout a 190-d lactation. Cows were born in late winter, early spring, and late spring calving systems, with varied weaning ages in 2000 and 2001, as described in Grings et al. (2005). Weaning age of dams as calves was 190 or 240 d of age for late winter and early spring calving systems and 140 and 190 d of age for late spring calving systems. Management from weaning to breeding was described in Grings et al. (2007) and included a comparison of heifers raised in a constant-gain system with those raised in a delayed-gain system. Cows were selected for the milk yield study to provide equal representation of pre- and postweaning management treatments. However, because postweaning management strategies had minimal effects on subsequent performance, they were not considered in this study. Management of calving systems during the period of the current study is described below.

Study Site

This study was conducted at the Fort Keogh Livestock and Range Research Laboratory near Miles City, MT (46°22′ N 105°5′ W). The potential natural vegetation is a grama-needlegrass-wheatgrass (*Bouteloua-Hesperostipa-Pascopyrum*) mixed grass dominant (Kuchler, 1964). Climate is continental and semiarid. Average annual rainfall in this area is 343 mm, with 60% received during the 150-d mid-April to mid-September growing season. Average daily temperatures range from –10°C in January to 24°C in July. Precipitation patterns for 2002 and 2003 are presented in Figure 1.

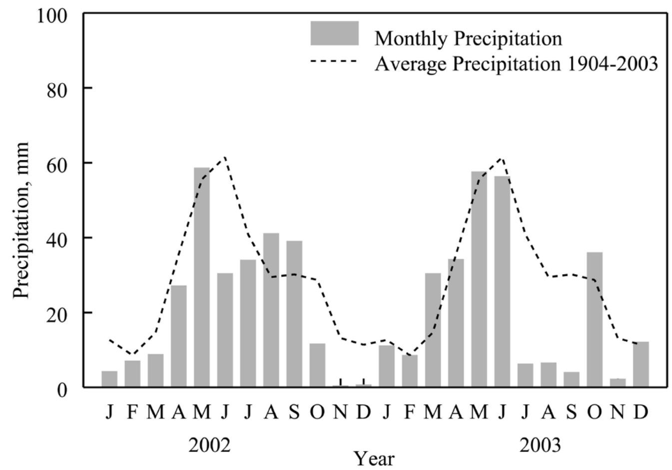

Figure 1. Precipitation during 2002 and 2003 at Miles City, MT (National Oceanic and Atmospheric Administration, 2002–2003).

Calving Systems

Cows and their calves were born into the same calving system, with average calving dates during the 2 yr of this study of February 4 ± 2 d for late winter, March 30 ± 2 d for early spring, and May 26 ± 1 d for late spring. Cows were sired predominantly by composite bulls (50% Red Angus, 25% Charolais, 25% Tarentaise) with crossbred dams of varied genetic backgrounds, including some combinations of Hereford, Limousin, Charolais, and composite breeding. In 2002, calves of these cows were sired by bulls that were three-fourths Hereford and one-fourth composite breeding, whereas in 2003 calves were sired by Angus bulls. Breeding was from approximately April 6 to May 9, June 6 to July 9, and August 6 to September 9 (exact dates varied by year) for the late winter, early spring, and late spring calving systems, respectively. Calves averaged 190 d of age at weaning, with weaning dates of August 14, October 7, and December 3 for the late winter, early spring, and late spring calving systems, respectively. Each calving herd was managed separately throughout the year, with harvested feed inputs appropriate for the specific calving season. Quantity and quality of hay and supplements were provided based on forage and weather conditions, physiological state of the cows, and available harvested feed resources within a year (Table 1). Pelleted supplements (1.9-cm pellet) were fed on the ground from a calibrated range cake feeder and the quantity was recorded daily. The number of hay bales fed was recorded and periodic weights of bales were taken to calculate the quantity of hay offered. Trace mineralized salt was available at all times.

Milk Yield Study

During the period of milk production measurement, primiparous cows were maintained primarily on native rangeland. However, hay, pelleted supplement, or both

Table 1. Feed source and estimated CP and TDN intakes for supplemental feeds[1] that were offered before the milk yield measures, when harvested feeds were provided to lactating primiparous beef cows grazing native rangeland

Calving system	Day of lactation	Year	Calendar date	Feed source	CP,[2] kg/d	TDN,[2] kg/d
Late winter	24	1	Feb. 27	Pelleted alfalfa, oat hay	1.1	4.6
Late winter	44	1	Mar. 19	Pelleted alfalfa, oat hay	1.1	4.6
Late winter	60	1	Apr. 4	Alfalfa hay	0.5	1.6
Late winter	19	2	Feb. 19	Pelleted supplement,[1] barley hay	1.4	5.7
Late winter	39	2	Mar. 11	Pelleted alfalfa, alfalfa hay, barley hay	1.2	5.0
Late winter	55	2	Mar. 27	Pelleted supplement,[1] alfalfa hay, barley hay	1.9	6.8
Early spring	16	2	Apr. 11	Alfalfa hay	0.5	1.8

[1]Pelleted supplement was a barley-based, 1.9-cm pellet with an estimated nutrient composition (DM basis) of 33.9% CP, 16.3% ADF, and 76.7% TDN.

[2]Amounts of estimated CP and TDN were based on feeds offered for a 1-wk period before the milk yield measures.

were provided to late winter cows through the third milk yield measurement and to the early spring cows through the first milk yield measurement of 2003 (Table 1). No supplemental feed was provided to the late spring cows during lactation.

After calving, cows selected for milk production measures from each calving system (2002, n = 20; 2003, n = 24 per calving system) were managed in 3 groups (1 for each system), which were moved to new pastures as dictated by forage availability. Cows were selected to provide an even number from each of the previous weaning and postweaning management strategies. Within each calving system, cows were selected by calving date from within heifer weaning age and development treatment to obtain as little variation in calving date as possible. Cows and calves were weighed within 48 h after calving, and cows were weighed before the beginning of the breeding season (approximately 60 d of lactation) and at weaning. At the beginning of the breeding season, cows were weighed in the morning after gathering from the pastures. At weaning, cows were weighed after the milk yield measurement, and weights were therefore shrunk weights. Body condition scores were assigned to cows (scale of 1 to 9; Herd and Sprott, 1986) at each BW measurement by palpation over the back and ribs by 2 technicians.

Milk production was measured by using the weigh-suckle-weigh technique on 7 occasions for each calving system. Milk yield of all cows within a calving system was measured on a single day, with average days in milk at milk yield measures of 20, 38, 55, 88, 125, 163, and 190 d. Cows and calves were paired in groups of 6 to 8 to facilitate the weigh-suckle-weigh procedures. Calves were separated from their dams for 8 h, allowed to suckle until full, and separated again for 12 h. Calves were then weighed, allowed to suckle until full, and reweighed. Milk yield was calculated as the difference between the pre- and postsuckling weights. Milk yield was multiplied by 2 to obtain 24-h milk production estimates for calculation of total yield.

Average daily gain from birth to weaning for calves was calculated by subtracting birth weight from weaning weight and dividing by the day of age at weaning. Average daily gain for cows was calculated for the intervals between calving and the beginning of breeding, from the beginning of breeding to weaning, and overall from calving to weaning.

Forage and Diet Sampling

At the time of each milk yield measure, pasture forage samples were collected to determine the quantity of forage available to provide a description of the study environment. Triplicate herbage sample sites were subjectively located in each sample pasture on each of 3 topographic positions (upland, hillside, and bottomland). The herbage in fifteen 0.1-m^2, randomly located quadrats was harvested by herbage type (grass or forb) to ground level, dried at 60°C in a forced-air oven (Hotpack Tru Temp Model 214300, Hotpack Corp., Philadelphia, PA), and weighed.

Diet quality during the grazing periods was estimated from esophageal extrusa. Extrusa samples were collected within a week of milk yield measures for each calving system. Extrusa samples were collected by using 4 to 7 multiparous, esophageally cannulated cows in each pasture during a 30- to 45-min period. Cannulated cows calved during spring, with a calving season longer than the early spring herd used in this study, and the calves were weaned in October. Previous research at this location has indicated that physiological state does not affect diet selection in late autumn, when the opportunity for selection is minimized (Grings et al., 2001). Cows had previous grazing experience in all pastures and were familiar with the vegetation types being grazed. Before each extrusa sample collection, cows were penned overnight with access to water but without food. Extrusa samples for the late winter calving system were not collected at the second milk yield period in 2002 or at the first and second milk yield periods for 2003, because snow cover precluded grazing at that time. Extrusa samples were lyophilized, ground to pass a 1-mm screen in a Wiley mill (Arthur A. Thomas, Philadelphia, PA), and stored until analysis.

Extrusa samples were analyzed for DM, ash (methods 930.15 and 942.05, respectively; AOAC, 1990), and CP. Samples for CP determination were placed in a roller grinder for 12 h (Mortenson, 2003). Nitrogen was determined by combustion techniques in a C-N (Flash EA1112, CE Elantech, Inc., Lakewood, NJ) analyzer. Nitrogen was multiplied by 6.25 to obtain CP, and these values were expressed on an OM basis. Extrusa samples were also analyzed for in vitro OM digestibility (**IVOMD**) by the method of Tilley and Terry (1963).

Statistical Analysis

Milk yield for the entire lactation period was calculated as area under the curve by trapezoidal summation using GraphPad Prism software (GraphPad Software Inc., San Diego, CA). Use of this technique to calculate milk yield accounted for the differing shapes of the lactation curves associated with calving systems. Yield and day of peak milk production were also calculated by using this software.

A total of 12 milk production values were not used because of obvious weighing errors during the weigh-suckle-weigh procedure. If these weighing errors were at the final milk measure, total yield values were not included in the data analysis (6 occurrences: 4 in the early spring calving system in 2002; 2 in the late spring calving system in 2003). Total milk yield data were not used from 2 late winter cows in 2003 with calves that were less than 165 d of age at weaning.

Calving system (n = 3) and weaning age of dam within calving system (n = 2) created 6 treatments. Milk yield and animal performance data were analyzed by using PROC MIXED (SAS Inst. Inc., Cary, NC). An initial statistical analysis was conducted with 12 heifer treatments, as described in Grings et al. (2007). Because of a lack of an effect ($P > 0.10$) of postweaning treatment on milk and weight variables, this term was not included in the final model, simplifying the experimental design to 6 treatments. Terms in the model included calf sex, treatment, year, and the year × treatment interaction as fixed class effects and day of age at the final milk yield measurement (weaning) as a covariate. Year effects were included as fixed effects to evaluate the impact of measured environmental differences among years. Orthogonal contrasts were used to evaluate treatment and year × treatment interactions. The following contrasts were used to describe treatment effects: 1) late winter vs. early spring calving system; 2) late spring vs. the average of the late winter and early spring calving systems; 3) 190 vs. 240 d of age at weaning as calves for cows in the late winter calving system; 4) 190 vs. 240 d of age at weaning as calves for cows in the early spring calving system; and 5) 140 vs. 190 d of age at weaning as calves for cows in the late spring calving system.

Pregnancy was diagnosed by transrectal ultrasonography in the fall. The proportion of cows pregnant was tested by using the CATMOD procedures of SAS, with a model that included calving system, year, and the calving system × year interaction.

Total herbage standing crops were calculated for sampled pastures by proportionally multiplying the estimated topographic site standing crop by the topographic composition of the pasture. Results are presented as unadjusted means that were obtained by averaging all standing crop estimates for each calving system across all dates within each year.

Extrusa quality data were analyzed by using mixed model procedures of SAS. Because cows reared from different weaning ages were grazing together under the same environmental conditions during lactation, the experimental model was decreased to evaluate only calving system effects, along with interactions including calving system. Terms in the model included calving system, year, and the year × calving system interaction as fixed class effects. Year effects were included as fixed effects to evaluate the impact of the measured environmental differences among years.

Path analysis was conducted to evaluate direct and indirect effects of various measures on calf ADG (kg/d) from birth to weaning and total milk yield (kg). An initial model for milk yield included year, weaning age of calf (day), the 5 orthogonal treatment contrasts, average forage standing crop (kg/ha), average forage CP yield (kg/ha), average dietary CP (DM basis), and dietary IVOMD. Dietary CP and IVOMD were estimated by using extrusa CP and IVOMD, and the estimated intakes and measured chemical composition of supplemental feeds (Table 1). Estimates of intake of supplemental feed were based on the record of feeds offered for 1 wk before milk yield measures. The model for ADG included the same terms and, additionally, calf sex. The diet quality and forage yield measures explained all of the variation attributable to between-year effects; therefore, year was arbitrarily removed from the model. The models were reduced in a backward stepwise elimination of least significant terms until $F > 1.3$ for all terms remaining in both models. The final models were tested against models containing year, treatment, and the year × treatment interaction. The mean square error was found to be greater in the models containing year × treatment than in the final models. Path diagrams were then constructed by using standard procedures to indicate the direct causal effects on milk yield and calf ADG, indirect effects through total milk yield on calf ADG, and correlations between the effects.

RESULTS AND DISCUSSION

Environmental Conditions

Precipitation patterns differed between the 2 yr of the study (Figure 1). Although both years had similar total precipitation levels, timing of precipitation was quite different. Precipitation was 264 mm in 2002 and 266 mm in 2003; both of these were less than the long-term yearly average of 343 mm. In 2002, late summer

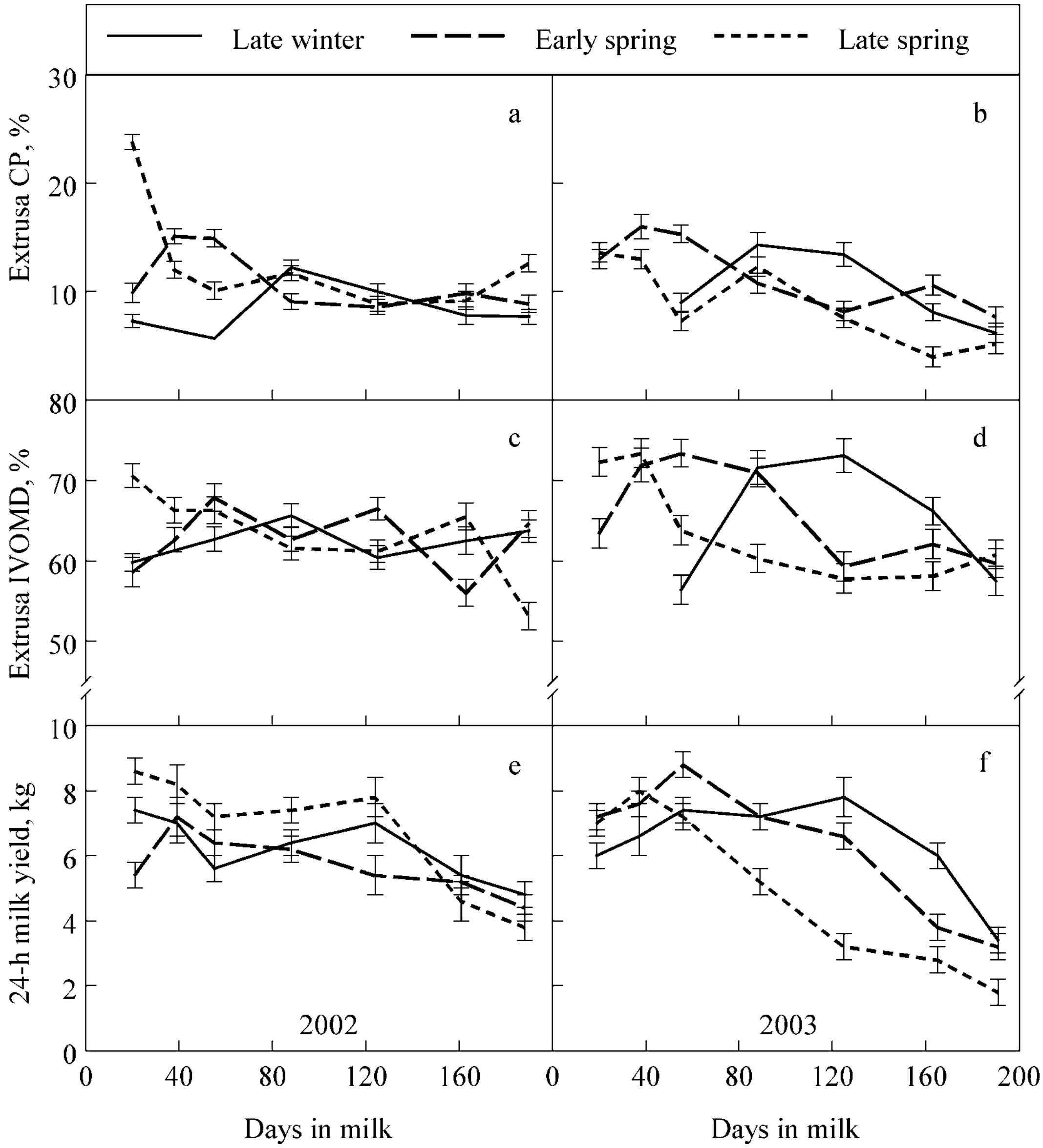

Figure 2. Means of CP (a and b, %) and in vitro OM digestibility (IVOMD; c and d, %) for extrusa collected at the time of milk yield measurements, and 24-h milk yield (e and f, kg) for primiparous cows from 3 calving systems (late winter, early spring, late spring) in 2002 (a, c, and e) and 2003 (b, d, and f). In addition to range forage, supplemental feed was provided to late winter cows through the third milk yield measurement and to the early spring cows through the first milk yield measurement in 2003. Supplemental feed was not provided to the late spring cows during lactation. No diet samples were collected at the second milk yield period in 2002 or the first and second milk yield period for 2003 for the late winter calving system because snow cover precluded grazing at those times. Bars show ± SE.

precipitation was increased over normal, and in 2003, precipitation was well below normal during this same period. July through September precipitation in 2002 was 14 mm above normal for this period, whereas the same period in 2003 was 84 mm below the long-term average.

Diet Quality and Forage Quantity

Figure 2 shows the composition of CP and IVOMD for extrusa samples collected throughout the study. Data are placed on the graph in relation to the days in milk for cows from each calving system.

The majority of the growth of the predominant cool-season grasses at this location occurs before July 1 (Kruse et al., 2007). Greater differences in extrusa quality associated with stage of lactation among calving systems occurred in 2003 compared with 2002, especially for IVOMD (Figure 2). These results were associated with below-average precipitation from July through September 2003, which caused a rapid decline in forage quality. A decline in forage quality is typical

Table 2. Probability values of effect estimates for contrasts evaluating effects of calving systems [late winter (LW), early spring (ES) or late spring (LS)] and dam weaning age (140, 190, or 240 d of age) on milk yield and calf gain for primiparous beef cows grazing native rangeland

	Milk			Calf	
Contrast	Total 190-d yield, kg	Day of peak	Peak yield, kg/d	ADG, kg/d	Weaning BW, kg
Effect of calving system					
LW vs. ES calving system	0.419	0.007	0.267	0.003	<0.001
LS vs. average of LW and ES calving systems	0.089	0.004	<0.001	<0.001	<0.001
Effect of weaning age of dam					
190 vs. 240 d of age for the LW calving system	0.873	0.061	0.887	0.551	0.647
190 vs. 240 d of age for the ES calving system	0.581	0.959	0.642	0.827	0.829
140 vs. 190 d of age for the LS calving system	0.050	0.333	<0.001	0.062	0.076
Year × treatment interaction					
Year × (LW vs. ES calving system)	0.820	0.147	0.132	0.756	0.271
Year × (LS vs. average of LW and ES calving systems)	<0.001	0.245	0.001	<0.001	<0.001
Year × (190 vs. 240 d of age for the LW calving system)	0.512	0.033	0.997	0.815	0.628
Year × (190 vs. 240 d of age for the ES calving system)	0.400	0.451	0.656	0.345	0.412
Year × (140 vs. 190 d of age for the LS calving system)	0.506	0.621	0.131	0.257	0.466

for the later part of the growing season in the Northern Great Plains (Adams and Short, 1987; Grings et al., 2005). In 2002, differences in extrusa CP were apparent among calving seasons early in lactation, but diet quality was fairly similar among calving seasons in late lactation. The lack of differences was related to above-average precipitation late in the growing season in 2002. Increased precipitation in May through June of 2003 compared with 2002 allowed extrusa quality to remain high throughout much of the mid to late lactation for the late winter calving system. Average forage standing crop available during the 190-d lactation was 813 ± 110, 898 ± 66, and 985 ± 75 kg/ha in 2002 and 876 ± 243, 985 ± 75, and 636 ± 108 kg/ha in 2003 for the late winter, early spring, and late spring calving systems, respectively.

Calving Systems Effects

Although year effects were not significant for milk and calf gain measures ($P > 0.10$), treatment × year interactions existed for all measures ($P \leq 0.006$) except day of peak lactation. Total milk yield over the 190-d lactation tended ($P = 0.089$; Tables 2 and 3) to differ for the late spring compared with the late winter and early spring cows. Cows in the late spring calving system had greater milk yield in 2002 and lesser milk yield in 2003 compared with the other calving systems (year × treatment interaction, $P < 0.001$). The lowered milk yield in 2003 for the late spring cows may be related to the decrease in quality observed for extrusa during that portion of the year (Figure 2). The extrusa quality curves observed for 2003 are typical for this Northern Great Plains environment (Adams and Short, 1987; Grings et al., 2005) even though late summer precipitation was below the long-term average. Previous reports have indicated that beef cows respond to lower quality nutrition by decreased persistency of lactation (Jenkins and Ferrell, 1984; Arthur et al., 1997).

Day of peak milk yield differed among calving systems ($P = 0.002$), with cows in the late winter system peaking later ($P = 0.007$) than cows in the early spring system and those in the late spring system peaking earlier ($P = 0.004$) than those in the other 2 systems (Table 3). Average date of peak milk yield was May 4 for the late winter system, May 31 for the early spring system, and July 19 for the late spring system. Day of peak milk yield did not differ ($P = 0.84$) among years even though extrusa quality patterns differed between years (Figure 2). Reports of day of peak milk yield have varied for beef cattle and have ranged from 3 to 7 wk of lactation (Totusek et al., 1973; Kress and Anderson, 1974). Some of the difference between reports may be related to the nutritional regimen of the cows during lactation. Wood (1972) reported that peak yield in grazing dairy cows occurred in conjunction with the flush of spring forage growth regardless of season of calving; therefore, peak milk yield occurred earlier in summer-calving than winter-calving cows. Comparisons of extrusa quality curves with lactation curves (Figure 2) showed a response to changes in forage quality, even at the later stages of lactation. This agrees with reports in dairy cows indicating that feed changes can cause rapid changes in milk yield (Wood 1972).

Milk yield at peak lactation was affected ($P < 0.001$; Table 3) by treatment and showed a year × treatment interaction ($P = 0.006$). Cows in the late spring system differed ($P < 0.001$; Tables 2 and 3) in yield at peak lactation from those in the late winter and early spring calving systems, but the comparison differed among years ($P < 0.001$). Peak milk yield was greater in cows from the late spring calving system than in those from the other calving systems in 2002, but not in 2003. Peak milk in all treatment groups averaged from 8.2 to 13.1

Table 3. Least squares means of total milk yield, yield at peak lactation, day of peak lactation, and calf ADG measured in 2002 (year 1) and 2003 (year 2) for primiparous heifers from late winter (LW), early spring (ES), and late spring (LS) calving systems weaned at different 140, 190, or 240 d of age as calves

	Calving system							*F*-test for		
	LW		ES		LS					
Item	190	240	190	240	140	190	SE	Treatment	Year	Year × treatment
n										
Year 1	10	9	11	5	10	10				
Year 2	12	10	12	12	12	10				
Milk										
Total 190-d yield, kg										
Year 1	1,074	1,130	1,018	1,123	1,327	1,147	69.7	0.191	0.27	<0.001
Year 2	1,233	1,199	1,172	1,150	937	849				
Peak, d	96	73	60	60	45	57	12.1	0.002	0.84	0.135
Peak yield, kg										
Year 1	8.4	8.4	8.3	8.2	13.1	9.5	0.62	<0.001	0.45	0.006
Year 2	8.4	8.3	9.8	9.3	10.1	8.4				
Calf										
ADG, kg/d										
Year 1	0.94	0.96	0.90	0.87	0.92	0.90	0.27	<0.001	0.22	<0.001
Year 2	1.00	1.01	0.94	0.96	0.75	0.67				
Weaning weight, kg										
Year 1	215	220	202	196	213	207	5.5	<0.001	0.11	<0.001
Year 2	227	226	215	218	175	161				

kg/d. This is comparable to a study by Reynolds and Tyrrell (2000) in which Hereford × Angus primiparous cows were milked weekly, and the authors reported an average peak of 8.2 kg/d with a range in individual cows from 5.8 to 13.6 kg/d.

Calf ADG was greater ($P = 0.003$) in the late winter than in the early spring calving system (Table 3), and this effect was consistent across years (year × treatment contrast interaction, $P = 0.756$). The increased gain in the late winter calves resulted in increased ($P < 0.001$) weaning weights for calves in this calving system. The relationship of calf ADG between the late spring and other calving systems differed with year ($P < 0.001$). Calf ADG was less in 2003 than in 2002, consistent with the decreased milk yield observed in 2003 for the late spring calving system. Calf weaning weight followed the same patterns observed for calf ADG (Tables 2 and 3).

Cow BW ($P = 0.004$) and BCS ($P < 0.001$) at calving were affected by treatment because of a difference ($P < 0.001$; Table 4) between late winter and early spring cows, with late winter cows being heavier and in greater body condition at calving than early spring cows (Table 5). Late spring cows had greater ($P = 0.002$) BCS at calving than the average of the late winter and early spring cows. This difference was observed previously (Grings et al., 2005), with effects being more pronounced for multiparous than for primiparous cows. Cow BCS at calving was greater ($P = 0.002$) in 2003 than 2002. A year × treatment interaction was observed ($P = 0.02$) for cow BW, because the difference between the late winter and early spring calving seasons was less in 2003 than in 2002.

Cow BW at the beginning of the breeding season differed ($P < 0.001$) and cow BCS tended ($P = 0.08$) to differ by treatment and was associated with treatment differences in BW ($P < 0.001$) and BCS ($P = 0.002$) changes from calving to the breeding season (Table 5). Year × treatment interactions occurred for BW ($P < 0.001$) and BCS ($P = 0.03$) at the beginning of the breeding season and BW change from calving to breeding. Primiparous cows in the early spring calving system gained BW and BCS, whereas those in the late winter calving system either gained less than early spring cows (2002) or lost (2003) BW from calving to breeding and lost BCS during this time such that cows in these 2 calving systems did not differ in BW ($P = 0.39$) or BCS ($P = 0.32$) at the beginning of the breeding season. These differences in BW and BCS changes could be related to the later day of peak milk yield for the late winter calving system. Body weights and BCS were taken at approximately 60 d after calving. Peak milk yield did not occur in the late winter cows until approximately 85 d after calving (Table 3), which is during the breeding season. Cows in the early spring system reached peak milk yield by approximately 60 d postcalving, and milk yield declined during the breeding season for these cows. The change from BW gain in 2002 to BW loss in 2003 between calving and breeding for cows in the late winter system (Table 5) may be related to the increased milk yield observed for these cows in 2003 compared with 2002 (Table 3).

Cows in the late spring calving system gained BW from calving to breeding in both years, and BW and BW gain during this period were greater ($P < 0.001$) than the average of the cows from the late winter and

Table 4. Probability values of effect estimates for contrasts evaluating the effects of calving systems [late winter (LW), early spring (ES) or late spring (LS)] and dam weaning age (140, 190, or 240 d of age) cow BW and BCS characteristics for primiparous beef cows grazing native rangeland

Contrast	BW: At calving, kg	BW: At breeding, kg	BW: At weaning, kg	BW: Change 1[1]	BW: Change 2[2]	BCS: At calving	BCS: At breeding	BCS: At weaning	BCS: Change 1[1]	BCS: Change 2[2]
Effect of calving system										
LW vs. ES calving system	<0.001	0.388	0.549	<0.001	0.955	<0.001	0.324	0.051	<0.001	0.017
LS vs. average of LW and ES calving systems	0.522	<0.001	<0.001	<0.001	<0.001	0.002	0.018	<0.001	0.639	<0.001
Effect of weaning age of dam										
190 vs. 240 d of age for the LW calving system	0.434	0.140	0.314	0.582	0.943	0.459	0.129	0.694	0.046	0.210
190 vs. 240 d of age for the ES calving system	0.788	0.374	0.396	0.890	0.684	0.436	0.332	0.037	0.794	0.594
140 vs. 190 d of age for the LS calving system	0.342	0.933	0.098	0.064	0.012	0.254	0.599	0.003	0.166	0.107
Year × treatment interaction										
Year × (LW vs. ES calving system)	0.001	<0.001	0.488	<0.001	<0.001	0.011	0.010	0.705	0.589	0.004
Year × (LS vs. average of LW and ES calving systems)	0.418	0.01	0.366	<0.001	<0.001	0.135	0.122	0.830	0.932	0.086
Year × (190 vs. 240 d of age for the LW calving system)	0.851	0.833	0.583	0.183	0.539	0.693	0.091	0.265	0.499	0.360
Year × (190 vs. 240 d of age for the ES calving system)	0.076	0.216	0.415	0.986	0.986	0.473	0.999	0.816	0.856	0.868
Year × (140 vs. 190 d of age for the LS calving system)	0.883	0.529	0.945	0.821	0.478	0.777	0.993	0.266	0.959	0.427

[1]BW and BCS change 1 = change from calving to the beginning of the breeding season.
[2]BW and BCS change 2 = change from the beginning of the breeding season to weaning.

early spring calving systems. Cow BCS change from calving to breeding did not differ (P = 0.64) for late spring compared with the average of the other calving systems. Interactions (P < 0.001) between treatments and years were observed for both measures. Cows in the late spring calving system gained more BW in 2003 than in 2002 so that the differences between cows in the late spring system and those in the other systems were of a different magnitude (P < 0.001) between years. With lowered forage quality in 2003, cows in the late spring calving system produced less milk and gained more BW than in 2002. Environmental conditions, including forage quality, appeared to alter partitioning of nutrient use away from milk toward BW gain during the early postpartum period for the late spring cows in 2003. Holloway et al. (1985) evaluated milk yield and BW change in beef cows grazing fescue or fescue-legume pastures. They reported that when grazing the higher quality forage, Angus-Hereford cows appeared to partition the increased available nutrients to body fatness rather than milk yield, whereas Hereford and Angus cows partitioned increased available nutrients toward milk yield. These data indicate that differences in nutrient partitioning to milk and body fatness in response to forage quality can occur but that this effect has a genetic component. This is consistent with the research of Jenkins and Ferrell (1992), which suggests the breeds respond differently in milk yield and BW change with varied energy intake.

Cow BW (P = 0.004) and BCS (P < 0.001) at weaning differed by treatment, with lighter BW and lesser BCS for the late spring compared with the average of the late winter and early spring cows (P < 0.001; Table 5). No interactions with year existed for BW (P = 0.82) or BCS (P = 0.74) at weaning. The differences in treatment comparisons at weaning compared with other weighing times were associated with treatment (P < 0.001) and year × treatment interaction effects on BW (P < 0.001) and BCS (P = 0.02) change from breeding to weaning. Cows in the late winter calving system lost BW from breeding to weaning in 2002 and gained BW in 2003, reflecting the opposite effect observed for weight gain from calving to breeding between years. Cow BCS change did not reflect this difference in BW change from breeding to weaning between years. Overall, no difference in BW change from breeding to weaning was observed (P = 0.96) between the late winter and early spring calving systems, but patterns of BW change for the 2 calving systems differed between years (P < 0.001), with early spring cows gaining BW in 2002 and late winter cows losing BW during this period in 2002. In 2003, early spring cows gained less BW than late winter cows from breeding to weaning. For the early spring calving system, BCS change was positive in 2002 and negative in 2003. Extrusa quality in the latter part of lactation was similar between the 2 herds in 2002, so differences in BW change between calving systems in 2002 may result primarily from differences in the tim-

Table 5. Least squares means of BW and BW changes between calving, the beginning of the breeding season, and at weaning for primiparous heifers from late winter (LW), early spring (ES), and late spring (LS) calving systems weaned at different 140, 190, or 240 d of age as calves

	Calving system							*F*-test for		
	LW		ES		LS					
Item	190	240	190	240	140	190	SE	Treatment	Year	Year × treatment
BW, kg										
At calving										
Year 1	459	466	407	389	446	436	12.1	0.004	0.164	0.019
Year 2	443	454	428	452	450	436				
At beginning of breeding										
Year 1	474	487	435	431	468	474	10.8	0.001	0.556	<0.001
Year 2	423	442	455	477	501	494				
At weaning	464	481	458	472	417	444	11.8	0.004	0.880	0.816
BW change, kg										
From calving to beginning of breeding										
Year 1	13.7	26.0	32.7	31.9	28.4	38.9	6.5	<0.001	0.011	<0.001
Year 2	–22.5	–27.6	26.7	25.7	48.1	61.5				
From beginning of breeding to weaning										
Year 1	–5.1	–11.2	21.8	26.1	–45.0	–24.8	11.1	<0.001	0.730	<0.001
Year 2	35.8	43.6	4.3	9.0	–90.3	–54.4				
BCS										
At calving										
Year 1	5.1	5.2	4.2	4.2	5.3	5.3	0.18	<0.001	0.002	0.102
Year 2	5.2	5.4	4.9	5.2	5.5	5.3				
At beginning of breeding										
Year 1	5.0	4.5	4.5	4.7	5.0	5.1	0.017	0.082	0.001	0.030
Year 2	4.9	5.0	5.3	5.5	5.2	5.3				
At weaning	5.0	5.0	4.7	5.0	4.3	4.6	0.09	<0.001	0.849	0.746
BW change, kg										
From calving to beginning of breeding	–0.20	–0.63	0.35	0.29	–0.26	0.04	0.15	0.002	0.703	0.973
From beginning of breeding to weaning										
Year 1	0.06	0.43	0.26	0.32	–0.82	–0.42	0.167	<0.001	<0.001	0.023
Year 2	0.04	0.10	–0.64	–0.52	–0.86	–0.73				

ing of peak milk yield. In 2003, extrusa quality was greater for the late winter calving system during late lactation and may have provided more nutrients for weight gain.

Cows in the late spring calving system lost BW and BCS from breeding to weaning in both years (Table 5). Changes in BW and BCS differed ($P < 0.001$) from those observed for late winter and early spring cows, and this difference was greater in 2003 than in 2002 (year interaction with contrast for late spring vs. the average of late winter and early spring, $P < 0.001$). Cow BW and BCS loss in late lactation for the late spring cows is most likely associated with decreased extrusa quality (especially CP; Figure 2), forage quantity, and environmental conditions such as cold weather. Weaning for the late spring herd did not occur until the first week in December. In 2003, Miles City experienced 3 d of temperatures below –32°C in November (National Oceanic and Atmospheric Administration, 2002–2003).

Proportion of cows pregnant was not affected ($P > 0.10$) by calving system, year, or the calving system × year interaction (data for year and calving system × year interaction not shown). Proportion of cows pregnant averaged 0.81 ± 0.06 for late winter, 0.89 ± 0.05 for early spring, and 0.82 ± 0.06 for late spring calving systems. This is consistent with previous reports from this location (Grings et al., 2005). It is of interest to note that in 2003, when extrusa quality was low during the breeding season for late spring cows, cows showed decreased milk yield and no change in reproductive performance. This indicates that lactation is not always prioritized above conception in beef cows, and the prioritization process may reflect patterns of total nutrient intake rather than a single specific nutrient such as protein or energy.

Effect of Weaning Age of Dams

Weaning age of dam affected several characteristics of milk yield and subsequent calf growth in primiparous beef cows. With the exception of day of peak milk yield, no differences were found in milk measures or calf BW gains between dams that had been weaned at 190 vs. 240 d of age ($P = 0.55$). A tendency for an effect of weaning age of dam in the late winter system on day of peak milk yield was observed ($P = 0.06$), along with a year × cow weaning age interaction ($P = 0.03$) within the late winter calving system. Cows in the late winter system exhibited 2 peaks in response to extrusa quality changes (Figure 2), and there was some variation in which peak was greatest. Forage quality tends to be greatest in June in this region (Adams and Short, 1987), which corresponds to midlactation for cows in the late winter calving system. These cows appeared to increase their milk yield during this time, even though milk yield had previously begun to decline.

Within the late spring calving system, differences in total 190-d milk yield (P = 0.05), peak milk yield (P < 0.001), calf ADG (P = 0.06), and calf weaning weight (P = 0.08) were observed for cows that had been weaned as calves at either 140 or 190 d of age (Table 3). Total 190-d milk yield was 134 ± 67 kg greater and peak milk yield was 2.6 ± 0.6 (SED) kg greater in cows weaned at 140 d compared with 190 d of age. The difference in milk yield associated with dam weaning age did not differ with year [year × (140 vs. 190 d of age at weaning), all $P \geq 0.13$; Table 2], even though milk yield for cows in the late spring system was greater in 2002 than 2003.

Calves in the late spring calving system from dams that had been weaned at 140 d of age tended to have greater (P = 0.06) ADG than those from dams weaned at 190 d of age, reflecting the difference in total and peak milk yield. The tendency for increased ADG resulted in a tendency (P = 0.08) for increased weaning weight of calves from late spring dams weaned at 140 compared with 190 d of age.

Research in both dairy and beef heifers has shown an influence of rate of gain during the prepubertal period on subsequent milk yield. Sejrsen et al. (2000) suggested that the full milk yield potential was reached in Danish-Friesian heifers gaining between 600 and 700 g/d during the prepubertal period of approximately 3 mo to puberty. Sejrsen et al. (2000) also suggested that the prepubertal feeding level that results in decreased mammary development differs by breed, with optimal daily gains decreasing with decreasing genetic capacity for milk. The authors reported that BW gains above 350 g/d negatively affected mammary development in Jersey heifers.

Buskirk et al. (1996) reported some variation in milk yield response to prepubertal dietary energy in beef heifers. Milk yield was decreased for primiparous cows fed creep feed compared with those not receiving creep feed from 112 to 232 d of age. Differences in milk yield relative to prepubertal feeding may be related to increased fat deposition in heifers on high feed levels or an increase in parenchymal cell deposition during realimentation of heifers fed at a lesser rate of gain during a prepubertal period (Yambayamba and Price, 1997).

Body weight gain of the dams used in our study was approximately 950 g/d as suckling calves and was not affected by season of birth (Grings et al. 2005, using data from heifer calves only). However, late spring heifers weaned at 140 d gained only 289 g/d from weaning to 190 d of age compared with 550 g/d from 140 to 190 d of age for those weaned at 190 d (averaged across the postweaning management treatments described in Grings et al., 2007). Therefore, the slower rate of gain between 140 and 190 d of age for late spring heifers weaned at 140 d of age, compared with heifers still suckling dams until 190 d of age, may have affected mammary gland development and increased subsequent milk yield. Average daily gain of late spring heifers weaned at different ages did not differ over a longer time period of weaning to breeding when fed similar diets (Grings et al., 2007). Feeding varied diets to heifers weaned at different ages to meet nutritional demands of specific weight gain goals may alter the results of the impact of weaning age on subsequent milk yield.

Body weight changes during lactation differed among late spring cows that had been weaned as calves at differing ages, with those that had been weaned at 140 d of age tending to have lesser (P = 0.06) BW gain from calving to breeding and greater BW loss (P = 0.01) from breeding to weaning than late spring cows that had been weaned at 190 d of age (Table 5). Cow BCS loss from breeding to weaning was also greater (P < 0.001) in late spring cows weaned at 140 d of age compared with 190 d of age. The increased weight loss in cows that had been weaned at 140 d of age resulted in a tendency (P = 0.10) for decreased BW and decreased BCS (P = 0.003) of these cows at weaning of their first calf (Table 5). This is consistent with the increased milk yield observed for the cows weaned at 140 of age (Table 3), indicating that the increased milk yield came at the expense of BW gain.

Relationship of Milk and Treatment Effects on Calf ADG

A path diagram showing relationships among variables influencing milk yield and calf ADG is shown in Figure 3. The straight, single-headed arrows show direct causal relationships, with the number associated with the arrow being the standard partial regression, or path, coefficient (designated $p_{a=>b}$, indicating the coefficient of the path from variable a to b). Curved lines with double-headed arrows represent indirect effects through their correlation with other variables. Numbers associated with curved arrows are correlation coefficients for the variables at either end of the arrow.

The direct effect of milk yield on calf ADG was 0.58 (Figure 3), indicating that approximately 34% of the variation in calf ADG can be attributed directly to milk intake. This value is slightly lower than several other reports that have found more than 50% of the variation in calf gain to be associated with milk yield (Totusek et al., 1973; Arthur, et al., 1997). Sex of calf and weaning age both influenced calf ADG independently of milk yield ($p_{SEX=>ADG}$ = 0.29 and $p_{W\ AGE=>ADG}$ = 0.12, respectively). The differences between the late winter and early spring calving seasons in calf ADG include a direct effect ($p_{W\ TC4=>ADG}$ = 0.14) on ADG, which could indicate abiotic environmental effects on ADG between these 2 calving systems. The correlation of sex with this treatment comparison is likely related to a disproportionate number of calves of one sex in each calving system.

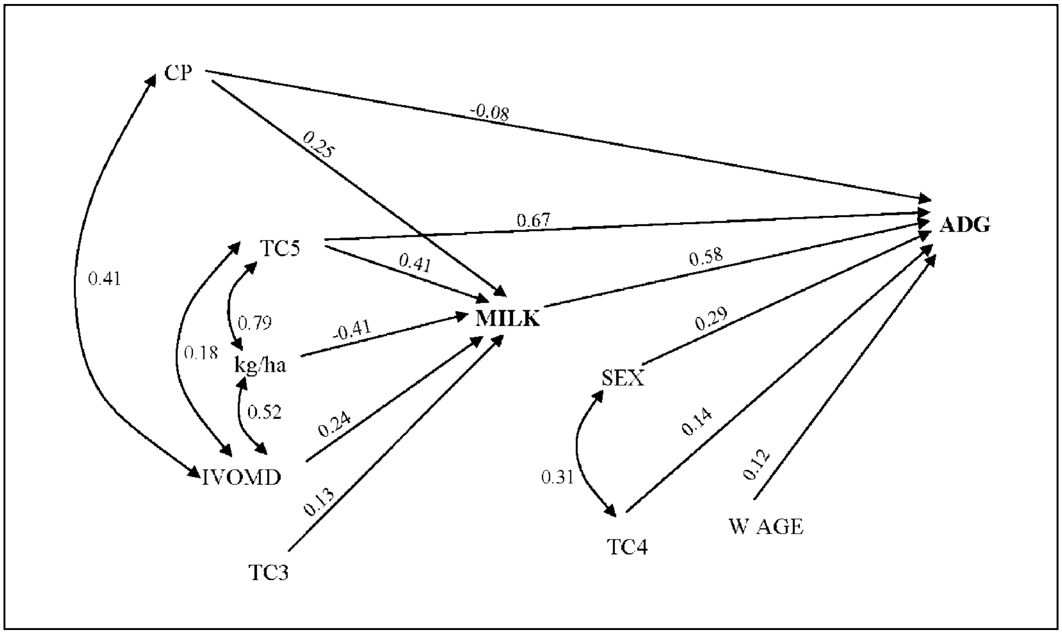

Figure 3. Path diagram showing direct and indirect relationships and correlations among total milk yield over a 190-d lactation (MILK), calf ADG from birth to weaning (ADG), average dietary CP (% of DM), average dietary in vitro OM digestibility (IVOMD), average forage standing crop (kg of DM/ha), calf sex (SEX), calf age at weaning (W AGE), and treatment contrasts (TC3, TC4, TC5). Contrasts are: TC3 = 140 vs. 190 d of age of dam at weaning, late spring calving system only; TC4 = late winter vs. early spring calving system; TC5 = late spring vs. the average of late winter and early spring calving systems. The straight, single-headed arrows show direct causal relationships, with the number associated with the arrow being the standard partial regression coefficient. Curved lines with double-headed arrows represent indirect effects through their correlation with other variables; numbers associated with curved arrows are correlation coefficients for the variables at either end of the arrow.

Because of a limited number of cows available from each treatment group, calf sex was not considered during assignment to this study. Heifer calves comprised 30% of the late winter calves, 68% of the early spring calves, and 57% of the late spring calves in this study.

Total average forage standing crop, estimated dietary CP, and IVOMD all influenced milk yield, as well as being correlated with one another and with the contrast comparing late spring to the average of the late winter and early spring calving systems. Dietary CP and IVOMD each accounted for approximately 6% of the variation in milk yield. A small direct relation ($p_{CP=>ADG} = -0.08$) of ADG from CP was observed, but no other diet or forage characteristics directly affected calf ADG. Diet and forage characteristics either directly influenced milk yield or had correlated responses to treatment effects.

The contrast of late spring to the average of the late winter and early spring calving systems influenced both milk yield ($p_{TC5=>MILK} = 0.41$) and ADG ($p_{TC5=>ADG} = 0.67$). The treatment contrast term was correlated with both forage quantity (kg/ha) and diet quality traits (CP, IVOMD), indicating that at least a portion of the difference in both milk yield and calf ADG is related to forage characteristics. It is important to note the greater coefficient for the direct effect of the treatment contrast comparing the late spring with the other calving systems (TC5) on calf ADG relative to that for milk. This could be the result of differences in intake and quality of forage consumed by calves, along with other unaccounted-for environmental factors, such as temperature effects on energy utilization.

The treatment contrast of dams in the late spring calving system that had been weaned at either 140 or 190 d of age as calves showed a direct causal relationship ($p_{TC3=>MILK} = 0.13$) to total milk yield. This indicates that the observed tendency for increased ADG between calves from late spring dams weaned at 140 vs. 190 d of age as calves (Table 3) is a response to the increased milk yield observed in those cows.

Season of calving and its associated management influences the time of peak milk and amount of milk yield in primiparous cows, corresponding to varied weight gains in their calves. Milk yield of cows in the late spring calving system was sensitive to diet quality. Weaning heifers at 140 vs. 190 d of age in the late spring calving system affected subsequent milk production during the first year of lactation, along with a tendency to affect calf weight and gain. Late spring calving affects calf ADG through joint effects on milk yield of the cow and other direct environmental effects on calf ADG. These environmental effects are likely a combination of forage quantity, diet quality, and weather-related effects. Understanding the impact of calving date on amounts and patterns of milk production can aid in developing management systems to best match the nutrient needs of cow-calf pairs in different calving systems.

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