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Effect of weaning regimen on energy profiles and reproductive performance of beef cows¹

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ABSTRACT: The effect of shifting calf-weaning age on profiles of energy status (BW, BCS, and rib and rump fat) and reproductive performance of beef cows was evaluated in a 3-yr study. Pregnant and lactating crossbred beef cows ($n = 408$), mainly of Angus and Hereford breeding, were stratified by age and by sex and BW of their calves and assigned randomly into 2 treatments: weaning at approximately 180 d (early weaning) and normal weaning 45 d later (control). Cows were managed together on native range pastures and supplemented with harvested forage during the winter months. Cow BW, BCS, rib fat, and rump fat were measured periodically from early weaning through the next breeding. Reproductive performance was evaluated by calving intervals (CI), days from initiation of breeding to calving (BCI), retention in the herd, and adjusted 205-d weaning BW of the subsequent calf. Early weaned cows had greater ($P < 0.001$) BW at normal weaning than control cows, but the overall pattern of cow BW did not differ ($P > 0.05$) among treatments. Peak and nadir BCS occurred at precalving and

postcalving periods, respectively and were greater ($P < 0.001$) at each period in early weaned than in control cows and in cows ≥ 5 -yr-old than in younger cows. Patterns for rib fat and rump fat were nearly identical to those of BCS except for the 3-way interaction ($P < 0.001$) of treatment, age, and period on rump fat. Mean CI (372.4 ± 2.1 d) and BCI (299.7 ± 1.9 d) were not affected ($P = 0.42$) by treatment but varied ($P < 0.001$) with age of the cow. Age of cow accounted for 16% of total variation in CI and 12% of total variation in gestation length ($P < 0.001$). The intervals were longer ($P < 0.001$) in primiparous cows than in older cows. Early weaning decreased risk of culling in cows and thereby increased ($P < 0.05$) overall persistence by 11% over control cows. Earlier weaning of cows in the previous year increased ($P < 0.001$) weaning weight of the subsequent calf by 8.6 kg per cow per yr. Shifting weaning time increased storage of consumed energy as evidenced by increased rump fat, for use later during high-energy demand, ultimately improving overall productivity of the cow-calf system.

Key words: beef cow, energy status, rump fat, weaning

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INTRODUCTION

Impact of prepartum nutrition on reproductive performance of beef cows was demonstrated by the pioneer work of Wiltbank et al. (1962). Subsequent researchers studied duration of feed restriction at different stages of gestation (Morrison et al., 1999) and cow age (DeRouen et al., 1994; Spitzer et al., 1995). Energy balance has a profound effect on duration of postpartum anestrus (Hess et al., 2005). Thus, a minimum BCS of 5 (multiparous beef cows) or 6 (primiparous beef cows) on a 9-point scale (Wagner et al., 1988) at calving is recommended for timely resumption of estrous cycles.

Nutrient requirements increase during pregnancy, but in temperate environments, nutrient availability may be inadequate during late gestation when requirements increase most rapidly. Therefore, cows must catabolize

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body tissue to support conceptus growth (Freetly et al., 2008). Supplementing grazed forages with harvested feed should prevent losing body tissue; however, cow feed efficiency to specific feed cost might be limiting. Freetly and Nienaber (1998) reported that time when feed resources are offered can be altered with minimal effect. Nutritionally, primiparous cows are affected most (Geary, 2003). Hence, pregnancy rates of 2- or 3-yr-old cows are often the least in the herd, and the effect is carried over to the second calving (Ottobre and Lewis, 1983; DeRouen et al., 1994). Reducing lactational stress by earlier weaning might lead to increased body energy reserves at calving and minimize the effects of negative energy balance on postpartum intervals and subsequent breeding performance. This alternative management practice could decrease postpartum interval, increase pregnancy rates, and increase longevity within a cow herd. Therefore, the objectives of this study were to evaluate the effect of shifting time of calf weaning on 1) cow body energy status throughout the production cycle and 2) postpartum reproductive efficiency.

MATERIALS AND METHODS

All experimental procedures were approved by the West Virginia University Animal Care and Use Committee.

Study Location, Animals, and Management

The study was conducted using a state-owned commercial beef herd in Huttonsville, WV. The farm is located in the Tygart Valley in Randolph County, West Virginia, adjacent to the Monongahela National Forest (38° 53' N, 79° 51' W). The average mean annual temperature at the Elkins-Randolph County Airport is 9.5°C. Three months have average mean temperatures below freezing, with -2.7°C in January being the coldest. Four months have average mean temperatures between 10 and 19°C, whereas temperatures in July (20.4°C) are the warmest. The elevation is about 625 m above sea level. The nearby Elkins airport receives, on average, 1,137 mm of precipitation annually, including 942 mm of rainfall and another 196 mm from melting of frozen precipitation (National Weather Service Forecast Office, 2008).

The breed composition in the herd was predominantly Angus with about 1/3 Hereford and Charolais crosses. Average cow age in the herd was 4.2 ± 1.7 yr, but ranged from 2 to 12 yr of age. Cows were managed on native range pastures all year round and supplemented with harvested forages during winter months. Forage species present in the pastures were primarily orchard grass (*Dactylis glomerata* L.), tall fescue (*Schedonorus phoenix*), white and red clover (*Trifolium repens* L. and *T. pratense* L.), and, in less proportion, Kentucky bluegrass (*Poa pratensis* L.) and timothy grass (*Phleum pratense* L.). Data were collected from 135 (yr 1) and 150 (in each of yr 2 and 3) spring-calving cows whose

calves averaged 6.0 ± 0.7 mo of age in September. Calving season began in early February and lasted until early April. Breeding season lasted 60 d during the study period beginning mid-May until mid-July. Cows were maintained in separate breeding age groups (2-, 3- to 4-, ≥ 5 -yr-old) during the breeding season. Bull to cow ratio was maintained at 1:20.

Cows were stratified by age and by sex and BW of their calves. Two treatments, early weaning at approximately 180 d of calf age (n = 90 yr 1, and 100 in each yr 2 and 3) and normal weaning 45 d later (control, n = 45 yr 1, and 50 in each yr 2 and 3), were assigned randomly to cows within strata. The study was conducted over a 12-mo period beginning at first weaning in September (early weaning) and ending at weaning of the next calf in September of the subsequent year and replicated for 3 yr. Time points of interest were 1) early weaning, 2) normal weaning, 3) precalving (average 3 wk before start of calving season), 4) postpartum (average 60 d after start of calving season), 5) breeding (average 30 d after end of calving season), and 6) end of breeding (60 d after start of breeding season). Cows were managed as 1 herd and reassigned among treatment groups each year throughout the study.

Measurements and Data Collection

Body weights were recorded and BCS were assigned to the cows by visual appraisal by a single evaluator at each weighing period based on a scale of 1 to 9 (1 = thin and 9 = obese; Wagner et al., 1988). Fat thickness was measured over the rump and rib using an Aloka 500 ultrasound console and a 5.0 MHz probe (Aloka America, Wallingford, CT). The transducer was placed above the interface between the biceps femoris and the gluteus medius muscles for rump fat, and on the intercostal region between the 12th and 13th rib for rib fat. The ultrasound images were analyzed at the National Centralized Ultrasound Processing Laboratories. Pregnancy diagnosis was performed at the end of each breeding period by transrectal ultrasonography using an Aloka 900 console with a 7.0 MHz probe (Aloka America). Calving interval was calculated as the interval from one calving to the next. Days from breeding to calving (**BCI**) were calculated as the number of days from start of breeding season to actual calving date. Calving and weaning rates in subsequent years were used as indicators of production efficiency in the herd. Cow retention pattern in the herd was indicated by the frequency of calving and weaning within the 3-yr study period.

Statistical Analysis

Data on cow BW, BCS, rib and rump fat, and composition scans were analyzed as repeated measures in a split plot design using the mixed procedures (SAS Inst. Inc., Cary, NC) according to the following model:

$$Y_{ijklm} = \mu + T_i + C_j + TC_{ij} + \Psi_{k(ij)} + B_l + TB_{il} \\ + CB_{jl} + \Psi B_{kl(ij)} + TCB_{ijl} + \varepsilon_{m(ijkl)},$$

where μ = overall mean; T_i = effect of *i*th treatment; C_j = effect of *j*th age group; TC_{ij} = interaction term for *i*th treatment and *j*th age group; $\Psi_{k(ij)}$ = subject (cow) effect nested within treatment and age group; B_l = effect of *l*th period; TB_{il} = interaction term for *i*th treatment and *l*th period; CB_{jl} = interaction term for *j*th age group and *l*th period; $\Psi B_{kl(ij)}$ = subject (cow) \times period interaction; TCB_{ijl} = treatment \times age \times period interaction; $\varepsilon_{m(ijkl)}$ = error term. Linear, quadratic, and cubic contrasts were tested for age and period effects at $\alpha = 0.05$.

Effects of cow age on BW and rump fat were further evaluated using the GLM procedures (SAS Inst. Inc.) in a second model that adjusted the variables to a constant BCS (5.0). The model statement is shown below:

$$Y_{ij} = \mu + T_i + B_{ij} + \varepsilon_{ij},$$

where μ = overall mean; T_i = effect of *i*th age; B_{ij} = mean value of covariate (BCS); ε_{ij} = error term. Least squares means differences were determined by Tukey's multiple comparison tests at $P \leq 0.05$.

Reproductive performance was evaluated in terms of 1) retention in the herd, which was obtained from proportion of cows that weaned calves ($\times 100 = \%$ retention) of those present at previous breeding season, 2) number of days from start of breeding period until calf birth (BCI), 3) calving interval (CI), and 4) performance of the subsequent calf. Cows that calved and subsequently weaned that calf were assigned a value of 1, and those that had no calf were assigned a value of 0. Calf performance was evaluated by adjusted 205-d weaning weight. Analyses for BCI, CI, and calf performance were evaluated using GLM procedure (SAS Inst. Inc.) according to the following model:

$$Y_{ijkl} = \mu + T_i + C_k + TC_{ik} + B_{j(i)} + e_{ijkl},$$

where Y_{ijkl} = the *l*th cow of the *j*th year in the *i*th treatment in the *k*th age group; μ = overall mean; T_i = effect of the *i*th treatment; C_k = effect of the *k*th age group; TC_{ik} = interaction term for the *i*th treatment and *k*th age group; $B_{j(i)}$ = effect of the *j*th year in the *i*th treatment; and e_{ijkl} = random error associated with Y_{ijkl} .

Least squares mean differences were determined by Tukey's LSD at $\alpha = 0.05$. Retention pattern was analyzed by contingency tables using JMP (SAS Inst. Inc.). Relationships between BCI, CI, cow age, BCS, and rib and rump fats were determined by polynomial analysis using JMP. Pairwise correlations were performed among all energy variables with reproductive variables at selected periods using JMP.

RESULTS AND DISCUSSION

Complete data sets were available for 408 cows for BW, BCS, and rib and rump fat analysis, 314 cows for CI and BCI analysis, and 252 cows for evaluation of subsequent adjusted 205-d calf weaning weights.

Cow BW

Weaning treatment did not influence ($P = 0.34$) overall cow BW profile throughout the production cycle. However, an interaction of treatment with period ($P < 0.001$) affected BW at normal weaning time (data not shown). Hence, upon cessation of suckling, control cows were able to compensate for reduced BW gain during the interval from early to normal weaning. A linear response ($P < 0.001$) for cow age by BW indicated BW increased rapidly between 2 to 4 yr of age and marginal BW gains thereafter (Table 1). Younger cows were generally lighter at most BW measurement with the exception of 5- and 6-yr-old cows, who were similar at all time points ($P < 0.001$). Body weights at normal weaning and precalving were greatest in cows 4 yr of age or older and least in 2-yr-old cows ($P < 0.001$). Postpartum BW remained low from calving to breeding but recovered at end of breeding to early weaning levels. In a second statistical model, the variability in cow BW with age was evaluated at a constant BCS. Similar to the unadjusted BW, a linear trend was observed for BW adjusted for age at BCS = 5.0 (Figure 1). Previous reports indicated that a BCS of 5.0 at calving and increasing BCS at breeding are important for improved reproductive efficiency in postpartum beef cows (Houghton et al., 1990a,b).

Renquist et al. (2006) monitored BW changes in fall-calving-beef cows at 4 periods (calving, breeding, weaning, and mid-gestation) and reported that growth from 3 to 5 yr of age caused differences of 28, 46, and 18 kg of BW between 3- and 4-, 3- and 5-, and 4- and 5-yr-old cows, respectively. Other investigators have shown that cow BW changed with age; however, the age at which mature BW was reached and the existence of a subsequent decline in BW have been subject to debate. Northcutt et al. (1992) and Tennant et al. (2002) showed that maximum BW accretion occurred between ages 5 and 6 yr. In contrast, Marlowe and Morrow (1985), Choy et al. (2002), and Renquist et al. (2006) reported that mature BW is attained at 7 to 8 yr of age. Furthermore, Northcutt et al. (1992), Tennant et al. (2002), and Renquist et al. (2006) found that cow BW declined after 11 yr of age. The present results agree with the latter studies.

BCS

Profiles of BCS followed a similar pattern as BW (Table 1). Weaning treatment and age \times treatment interactions affected ($P < 0.001$) BCS pattern. Early weaned 3- and 5-yr-old cows had greater ($P < 0.001$)

Table 1. Least squares means (\pm SE) of BW and BCS of cows 2 to ≥ 6 yr of age¹

Cow age, yr	n	Time period					
		Early weaning	Normal weaning	Precalving	End of calving	Breeding	End of breeding
BW, kg							
2	175	477.0 \pm 4.1 ^a	499.0 \pm 4.2 ^a	522.6 \pm 4.7 ^a	453.1 \pm 4.8 ^a	443.4 \pm 7.0 ^a	503.5 \pm 5.7 ^a
3	88	506.6 \pm 5.8 ^b	532.5 \pm 6.1 ^b	559.3 \pm 7.0 ^b	494.7 \pm 6.8 ^b	509.9 \pm 9.8 ^b	541.3 \pm 8.7 ^b
4	28	556.2 \pm 10.1 ^c	573.7 \pm 10.5 ^c	622.7 \pm 21.4 ^c	526.4 \pm 11.9 ^{bc}	536.3 \pm 17.4 ^{bc}	589.2 \pm 24.0 ^{bc}
5	42	594.1 \pm 8.5 ^d	612.5 \pm 8.9 ^d	650.3 \pm 9.3 ^c	554.6 \pm 10.2 ^c	555.6 \pm 14.6 ^{bc}	606.7 \pm 10.5 ^c
≥ 6	75	593.4 \pm 6.0 ^d	614.0 \pm 6.2 ^d	649.8 \pm 7.0 ^c	557.2 \pm 7.2 ^c	573.4 \pm 10.6 ^c	584.7 \pm 8.0 ^c
BCS ²							
2	175	5.4 \pm 0.1 ^a	5.6 \pm 0.1 ^a	5.5 \pm 0.1 ^a	4.6 \pm 0.1 ^a	5.0 \pm 0.1 ^a	5.6 \pm 0.1 ^a
3	88	5.4 \pm 0.1 ^a	5.8 \pm 0.1 ^{ab}	5.9 \pm 0.1 ^b	5.0 \pm 0.1 ^b	5.4 \pm 0.1 ^b	5.8 \pm 0.1 ^{ab}
4	28	5.9 \pm 0.1 ^b	6.2 \pm 0.1 ^b	6.0 \pm 0.3 ^{bc}	5.4 \pm 0.1 ^b	5.8 \pm 0.1 ^c	5.9 \pm 0.3 ^{ab}
5	42	5.8 \pm 0.1 ^b	6.4 \pm 0.1 ^b	6.3 \pm 0.1 ^c	5.1 \pm 0.1 ^b	5.5 \pm 0.1 ^{bc}	6.0 \pm 0.1 ^b
≥ 6	75	5.8 \pm 0.1 ^b	6.2 \pm 0.1 ^b	6.4 \pm 0.1 ^c	5.2 \pm 0.1 ^b	5.5 \pm 0.1 ^{bc}	5.9 \pm 0.1 ^{ab}

^{a-d}Least squares means (\pm SE) with unlike superscripts within columns differ ($P < 0.001$).

¹Early weaning, normal weaning, precalving, end of calving, breeding, and end of breeding are periodic measurements taken in September, October, January, April, and May over 3 yr, respectively. Age \times period ($P < 0.001$) for BW and BCS.

²BCS (1 = severely emaciated to 9 = obese; Wagner et al., 1988).

BCS than control 3- and 5-yr-old cows, whereas no differences occurred in other age groups. A linear increase ($P < 0.001$) in BCS was observed with age, and maximum BCS was generally achieved in cows ≥ 4 yr of age. Periodic fluctuations were observed and BCS peaked before calving, whereas nadir BCS occurred after calving in all age groups. Body condition fell by at least 1 full BCS unit from precalving to postpartum followed by a gradual increase at breeding. Maximum BCS was observed in ≥ 5 -yr-old cows at precalving, whereas minimum BCS was observed in 2-yr-old cows in the postpartum period. A similar profile in BCS was

reported by Renquist et al. (2006) with differences occurring between ages 3 and 4, 4 and 5, 5 and 6, 7, and 8 yr. They also reported a full point BCS decline across all age groups after calving as in the present study. The close link between BCS and BW profiles is consistent with previous findings, in which BCS reached a plateau at ages 5 (Marlowe and Morrow, 1985), and 6 to 8 yr (Choy et al., 2002), respectively. The finding that weaning can influence BCS at calving is consistent with previous published reports and might provide an alternative management strategy to improve subsequent reproductive performance of beef cows. Previous

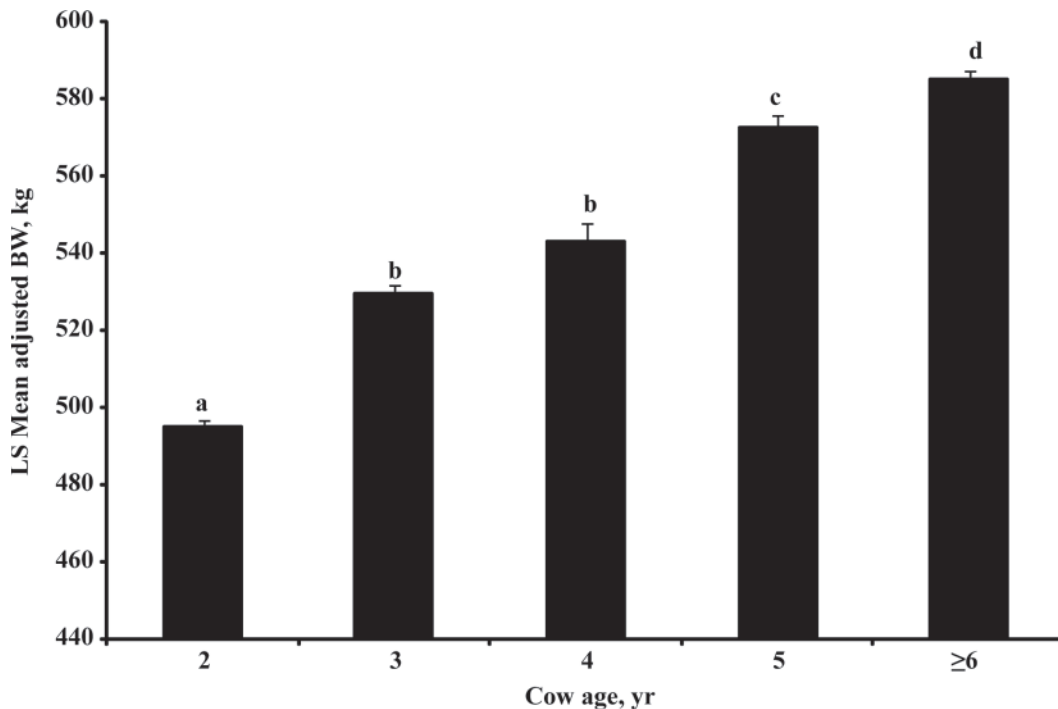


Figure 1. Least squares means (\pm SE) for cow BW (kg) adjusted to average BCS (5.0) for age categories (n = 175, 88, 28, 42, and 75 for 2-, 3-, 4-, 5-, and ≥ 6 -yr-old cows, respectively). ^{a-d}Least squares (LS) means without common letters differ ($P < 0.0001$).

Table 2. Least squares means (\pm SE) for rib fat of cows 2 to ≥ 6 yr of age¹

Cow age, yr	n	Time period				
		Early weaning	Normal weaning	Precalving	End of calving	Breeding
		Rib fat, mm				
2	175	2.8 \pm 0.2 ^a	3.4 \pm 0.2 ^a	3.5 \pm 0.2 ^a	1.6 \pm 0.1 ^a	1.9 \pm 0.1 ^a
3	88	2.9 \pm 0.2 ^a	4.4 \pm 0.3 ^b	5.3 \pm 0.4 ^b	2.0 \pm 0.2 ^{ab}	2.4 \pm 0.2 ^{ab}
4	28	5.4 \pm 0.4 ^c	7.6 \pm 0.5 ^d	11.3 \pm 1.1 ^d	2.5 \pm 0.3 ^{bc}	2.7 \pm 0.3 ^{bc}
5	42	3.9 \pm 0.3 ^b	6.0 \pm 0.4 ^{cd}	6.9 \pm 0.5 ^c	2.9 \pm 0.2 ^c	3.0 \pm 0.2 ^c
≥ 6	75	3.1 \pm 0.3 ^{ab}	5.3 \pm 0.3 ^{bc}	6.9 \pm 0.4 ^c	2.6 \pm 0.2 ^c	2.9 \pm 0.28 ^c

^{a-d}Least squares means (\pm SE) without common superscripts within columns differ ($P < 0.001$).

¹Early weaning, normal weaning, precalving, end of calving, and breeding are periodic measurements taken in September, October, January, April, and May over 3 yr, respectively. Age \times period ($P < 0.01$).

investigators have reported that BCS at calving is the single most important determinant of resumption of ovarian cyclicity (DeRouen et al., 1994; Spitzer et al., 1995; Morrison et al., 1999). Thus, the additional cost in supplementing cows in low BCS to achieve modest BCS at calving might be saved if a similar objective can be achieved by weaning calves before traditional weaning times. Such programs might have significant financial implications to livestock producers.

Rib Fat

Rib fat thickness followed a quadratic trend with cow age (Table 2; $P < 0.001$); it was least in 2- and 3-yr-old cows, peaked when cows were 4-yr-old, and declined by 5 yr of age. Weaning treatment and its interactions with age and with period affected ($P < 0.006$) rib fat thickness. Early weaned cows of at least 4 yr of age had greater ($P < 0.001$) rib fat thickness as opposed to 2- and 3-yr-old cows (data not shown). Because impetus for fat accretion occurs in the later stages of growth, nutrient homeorrhexis in younger cows could have been targeted preferentially to protein accretion (Hornick et al., 2000). Therefore, the impact of early weaning might not be detected by fat scans in this age group. The periodic pattern of rib fat profile followed a similar pattern as those of BCS and BW. Maximum values were observed precalving, whereas minimum values were observed postpartum in all age groups. The percentage

decline in rib fat between precalving and postpartum periods were 58, 62, 76, 67, and 61% for 2-, 3-, 4-, 5-, and ≥ 6 -yr-old cows, respectively.

Rump Fat

Rump fat thickness was affected by age, weaning treatment, period, and their 2- ($P < 0.05$) and 3-way interactions (Table 3; $P < 0.001$). Cow rump fat thickness was increased ($P < 0.001$) in the precalving periods and tended ($P = 0.07$) to be increased in the postcalving periods by early weaning treatment compared with control. This trend was consistent in all age groups except the 2-yr-old cows (Table 3). Thus, rump fat was the only objective measurement with detectable changes across all levels of independent factors. This finding indicates that rump fat might be an important noninvasive determinant of beef cow energy status. Adjustment of rump fat to an average BCS (5.0) displayed a quadratic trend ($P < 0.001$) for cow age (Figure 2).

Mobilization of adipose tissue is quantitatively a more important source of energy than body protein or liver glycogen (Schroder and Staufenbiel, 2006). Consequently, adipose tissue seems suitable to assess energy balance because the amount of mobilized body fat approximates the energy demand that is required for milk production and maintenance. Several attempts have been made to correct the variability in using BCS as a measure of energy status in beef and dairy cows

Table 3. Least squares means (\pm SE) for rump fat (mm) for age \times treatment and \times period^{1,2}

Age, yr	n	Early weaning		Normal weaning		Precalving		Postpartum		Breeding	
		Control	EW	Control	EW	Control	EW	Control	EW	Control	EW
2	175	4.2 \pm 0.4	3.8 \pm 0.3	4.6 \pm 0.4	5.4 \pm 0.3*	4.2 \pm 0.4	5.1 \pm 0.3	1.5 \pm 0.4	1.5 \pm 0.3	2.1 \pm 0.4	2.0 \pm 0.3
3	88	5.1 \pm 0.6	4.8 \pm 0.4	6.0 \pm 0.6	8.0 \pm 0.4**	6.9 \pm 0.6	8.0 \pm 0.4*	1.7 \pm 0.6	2.2 \pm 0.4	2.5 \pm 0.6	3.0 \pm 0.5
4	28	5.0 \pm 0.9	7.6 \pm 0.9*	6.8 \pm 0.9	13.4 \pm 0.9**	6.4 \pm 1.7	12.6 \pm 1.0**	1.9 \pm 0.9	4.1 \pm 0.9*	2.0 \pm 1.0	4.2 \pm 0.9*
5	42	4.2 \pm 1.1	6.3 \pm 0.6*	4.9 \pm 1.1	10.1 \pm 0.6**	6.6 \pm 1.1	10.3 \pm 0.6**	2.0 \pm 1.2	3.4 \pm 0.6	2.6 \pm 1.2	4.3 \pm 0.6
≥ 6	75	5.3 \pm 0.7	5.8 \pm 0.5	5.8 \pm 0.7	10.5 \pm 0.5**	7.9 \pm 0.7	12.0 \pm 0.5**	2.8 \pm 0.7	3.8 \pm 0.5	3.9 \pm 0.8	4.5 \pm 0.5

¹Early weaning, normal weaning, precalving, postpartum, and breeding are periodic measurements taken in September, October, January, April, and May, respectively. Treatments: early weaning at approximately 180 d of calf age (EW; n = 90 in yr 1, and 100 in each yr 2 and 3) and normal weaning 45 d later (control, n = 45 in yr 1, and 50 in each yr 2 and 3).

²Treatment \times period ($P < 0.005$). Treatment \times age \times period ($P < 0.001$).

*Least squares means (\pm SE) among treatments within periods differed ($P < 0.05$).

**Least squares means (\pm SE) among treatments within periods differed ($P < 0.01$).

Table 4. Least squares means (\pm SE) of calving intervals (CI) and breeding-to-calving interval (BCI) of cows with age, year, and treatment¹

Item	n	CI ¹	BCI ²
Age, yr			
2	143	375.4 \pm 1.9 ^a	303.5 \pm 1.6 ^a
3	68	364.1 \pm 3.3 ^b	292.5 \pm 2.8 ^b
4 and 5	44	373.6 \pm 5.8 ^{ab}	292.3 \pm 4.6 ^{ab}
≥ 6	59	372.3 \pm 2.5 ^{ab}	298.5 \pm 2.1 ^{ab}
Year			
2005–2006	159	378.3 \pm 2.5 ^a	297.4 \pm 2.0
2006–2007	155	365.2 \pm 2.5 ^b	294.3 \pm 2.0
Treatment			
Control	96	372.9 \pm 2.8	295.6 \pm 2.3
Early weaned	218	370.7 \pm 2.1	296.1 \pm 1.6

^{a,b}Least squares means without common superscripts within columns differ ($P < 0.05$).

¹CI = number of days from previous calving to next calving.

²BCI = number of days from start of breeding to next calving.

due to regional and individual score systems. Wagner (1984) and Buskirk et al. (1992) reported that 38-kg change in BW was associated with each unit change in BCS. Ferrell and Jenkins (1996) found a change of 51 kg of empty BW per unit BCS, whereas Tennant et al. (2002) reported that BW adjustments to BCS varied among time periods of the production cycle. These variations in BW per unit BCS among studies prompted an examination of alternative approaches in predicting energy status in cattle. An ultrasonic technique has been established to predict carcass quality in beef cattle (Brethour, 1992). A new aspect would be the application of ultrasound as a monitoring tool for nutritive status in herd management. Measurement of rump fat by ultrasound might be an added value compared with other condition scoring systems because of the objectivity and precision associated with the procedure. Repeatability of ultrasound measurements (Brethour,

1992) indicated reliability of ultrasound for predicting energy status in beef cows. The repeatability between consecutive measurements in that study was 0.975 with an absolute difference of 0.72 mm. Robinson et al. (1992) reported an average SD of 0.43 mm in repeated ultrasound measurements of fat within individual operators and approximately 1 mm when comparing measurements between different operators. Because of the 1-mm metering precision of the ultrasound technique, even slight changes in body condition that may not be appreciable using the BCS system can be determined and computed on an individual or herd basis. These data can be related to production variables to evaluate the effects of negative energy balance (Schroder and Staufenbiel, 2006).

Reproductive Performance

Reproductive performance was evaluated using CI, BCI, and calving pattern. Mean calving interval was 372.4 d, which varied ($P < 0.001$) with year and tended ($P = 0.06$) to be affected by cow age (Table 4), but not by weaning treatment ($P = 0.42$). Relationship of CI (Y) to cow age (X) was explained by polynomial fit: $Y = 321.9 + 11.2X + 6.3X^2 - 4.0X^3$ ($R^2 = 0.16$, $P < 0.001$). Two-year-old cows had the longest ($P < 0.05$) CI (375.4 \pm 1.9 d), whereas 3-yr-old cows had the shortest ($P < 0.05$) CI (364.1 \pm 3.3 d). Calving interval was negatively correlated ($r = -0.21$, $P < 0.01$) to ribfat thickness at breeding (Table 5).

Interval from breeding to calving differed ($P < 0.001$; Table 4) between 2- and 3-yr-old cows (303.5 \pm 1.6 vs. 292.5 \pm 2.8 d, respectively), but not in cows ≥ 4 yr of age. Relationship of BCI (Y) to cow age (X) was explained by polynomial fit: $Y = 280.4 + 2.9X + 4.5X^2 - 1.8X^3$ ($R^2 = 0.12$, $P < 0.001$). Interval from breeding to calving was negatively correlated to parturition

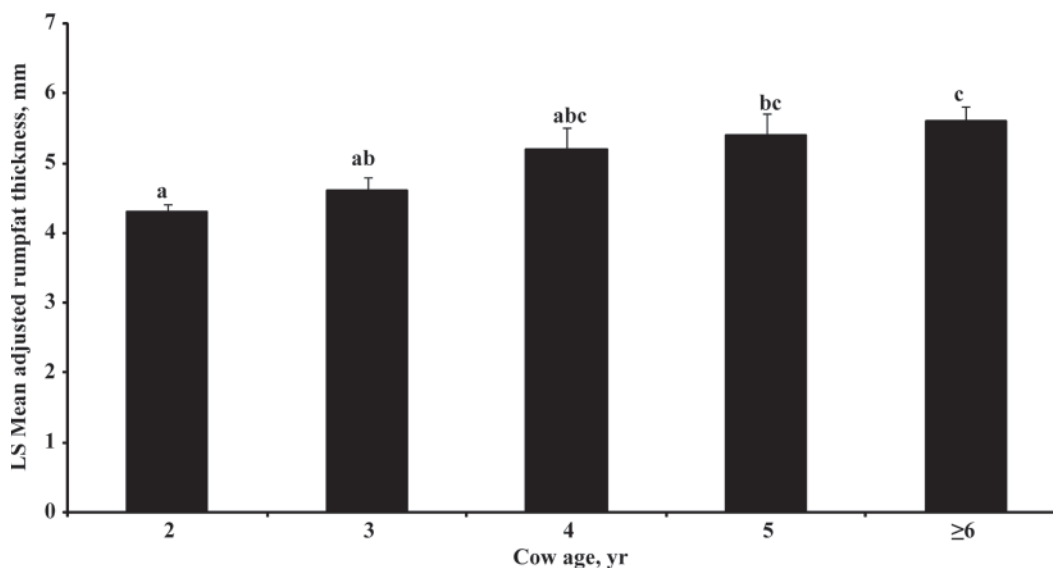


Figure 2. Least squares means (\pm SE) for cow rump fat thickness (mm) adjusted to average BCS (5.0) for every age category (n = 175, 88, 28, 42, and 75 for 2-, 3-, 4-, 5-, and ≥ 6 -yr-old cows, respectively). ^{a-c}Least squares (LS) means without common letters differ ($P < 0.0001$).

Table 5. Pairwise correlations of beef cow energy variables at selected periods with reproductive variables

Variable	n	Pregalving	n	Breeding
BCS	145	-0.02NS	144	-0.09NS
Rib fat	154	-0.05NS	155	-0.21**
Rump fat	153	-0.11NS	155	-0.12NS
BW	155	-0.09NS	155	-0.07NS
		BCI ²		
BCS	159	-0.17*	158	-0.27***
Rib fat	168	-0.25**	169	-0.23**
Rump fat	166	-0.27***	169	-0.22**
BW	169	-0.18*	169	-0.21**

¹CI = number of days from previous calving to next calving.

²BCI = days from initiation of breeding to calving.

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, NS = nonsignificant.

rump fat ($r = -0.27$, $P < 0.001$; Table 5) and to BCS at breeding ($r = -0.27$, $P < 0.001$; Table 5). These relationships were greater ($P < 0.001$) than those of BCI to rib fat, rump fat, and BW, at breeding or BCI to BCS rib fat and BW before calving.

Because adequate reproductive performance is essential to profitability, the effect of age on CI and BCI has a significant impact in beef cattle production. The longer ($P < 0.05$) CI and BCI between the first calving at 2 yr of age and calving at 3 yr of age might have resulted from increased postpartum anestrous intervals in primiparous cows. Previous researchers have noted a negative association of age and longer postpartum interval (Neville et al., 1990; Morris et al., 2006; Renquist et al., 2006) and attributed it to postpartum loss of BW and BCS in primiparous cows. The relationships described above and measures of energy status described in preceding sections support that hypothesis and indicate that losses in rump fat might be more accurate markers of energy status relevant to longer postpartum intervals than BW or BCS losses. Therefore, preferentially managing younger cows to minimize rib and rump fat losses up to their second calving as 3-yr-olds and subsequent rebreeding might shorten CI and BCI. Dystocia is more common in first-calf heifers and is presumed to delay rebreeding (Laster et al., 1973; Bellows and Short, 1978) by delaying uterine involution. Although calving difficulty was not monitored, this might explain the longer CI and BCI in the cows calving as 3-yr-olds. After 3 yr of age, there was little change in calving interval and BCI. These results indicate that once cows calve a second time, the effects of age on reproductive efficiency become minimal. Interactions of age with time of year of calving affected length of CI (Ottobre and Lewis, 1983). In that study, cows that calved from December to February had longer calving interval than those that calved from March to April. However, the effect was more pronounced in 2- and 3-yr-old cows than in older cows.

Table 6. Comparison of retention pattern (%) among cow age groups during the study

Age, yr	n	Retention pattern ¹		
		0	1	11
2	143	41.3 ^a	45.5 ^b	13.2 ^c
3	68	8.8 ^c	61.8 ^a	29.4 ^b
4 and 5	44	31.8 ^{ab}	20.5 ^c	47.7 ^a
≥6	59	15.3 ^b	28.8 ^c	55.9 ^a

^{a-c}Least squares means without common superscripts within columns differ ($P < 0.05$).

¹Retention pattern 0: Cows that did not wean a subsequent calf during the study period. Retention pattern 1: Cows that weaned a calf in only 1 yr of the study. Retention pattern 11: Cows weaned calves in both subsequent years of study.

Retention pattern in the herd was analyzed by contingency tables as percentage of cows exposed to breeding that successfully reared a subsequent calf to weaning after the first and second breeding seasons. A total of 314 cows were exposed to breeding. Retention pattern differed ($P < 0.05$) with treatment and age, and averaged 55.2 and 66.5% for control and early weaned cows, respectively (Table 6). Cows that did not calve or wean a calf the subsequent year and were eventually culled (retention pattern = 0) accounted for 28% of the total observations and were mainly 2-yr-old cows. Cows that calved and weaned a calf the subsequent year but not the third year (retention pattern = 1) accounted for 42.4% of total observations and were mainly 2- and 3-yr-old cows. Lastly, cows that calved and weaned calves after both breeding seasons (retention pattern = 11) accounted for 29.6% of the total observations and were mainly cows ≥ 4 yr old.

Retention in the herd was a function of pregnancy, calving, and culling rates. Being pregnant at the end of the breeding season, calving within the designated calving season, and successfully rearing a calf to weaning were requisites for cows to be retained in the herd. Cows were culled from the herd due to other reasons such as still birth, low calf BW at weaning, and poor body condition at breeding. However, these culling decisions were made independent of treatment. Early weaning decreased the proportion of cows culled by 11.3 percentage points or about 25%, from 44.8 to 33.5%. Body condition at breeding was an important factor in cow retention in the subsequent breeding season. Because more control cows exhibited poor condition at breeding, they were subsequently culled from the herd. The increased culling pressure practiced at the farm favored cows with greater BCS and might have influenced the differences in persistence among the 2 treatment groups despite both having similar pregnancy rates at end of breeding. Grings et al. (2005) reported that season of calving and age at weaning affected BW and BCS dynamics of beef cows, but did not change the proportion of cows that became pregnant after natural breeding. However, those authors did not evaluate persistence in

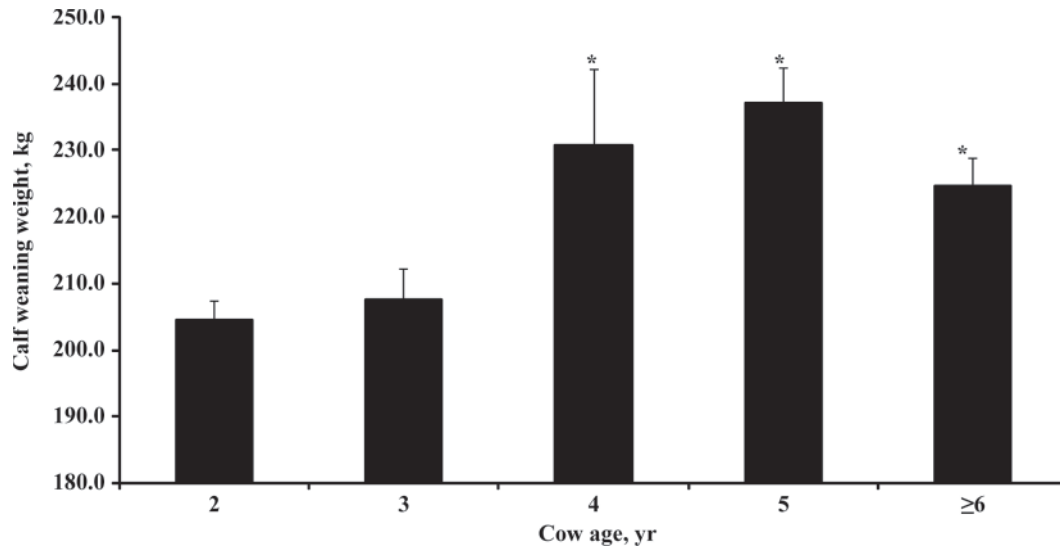


Figure 3. Least squares means \pm SE for calf adjusted 205-d weaning weights (kg) by cow age ($n = 106, 58, 20, 26,$ and 42 for 2-, 3-, 4-, 5-, and ≥ 6 -yr-old cows, respectively). *Weaning weights increased ($P < 0.0001$) in calves from cows ≥ 4 yr of age compared with their contemporaries from younger cows.

their herd and were not able to detect differences due to weaning age or season of calving.

Weaning Weights

Calf weaning weights in the subsequent year were affected by the previous weaning treatment of the dam, age, and year ($P < 0.001$). Calves from early-weaned cows were heavier at weaning (225.2 ± 3.1 kg) than their contemporaries from control cows (216.7 ± 4.1 kg), and from ≥ 4 yr-old cows than from 2- and 3-yr-old cows ($P < 0.001$; Figure 3). Weaning weights increased ($P < 0.001$) in yr 2 by 8% over yr 1 and might have been influenced by increased culling or better management during the study (data not shown). As expected (Richardson et al., 1978; Baker and Boyd, 2003), steer calf BW at weaning were greater ($P < 0.001$) than those of heifer calves (226.4 vs. 215.5 kg).

The effect of age of the dam on calf weaning weight has been reported (Melton et al., 1967; Vargas et al., 1999; Baker and Boyd, 2003) and might be explained by decreased birth weights and milk production in 2-yr-olds. Primiparous cows are usually bred to reduced birth weight bulls to minimize incidences of dystocia. However, this emphasis on reduced birth weights might in turn result in lighter weaning weights of their calves. Vargas et al. (1999) attributed reduced weaning weights of calves from primiparous cows to the small frame size and low body condition of the latter. In the current study, energy status of 2-yr-old cows were persistently low throughout and were not affected by treatment. This observation confirmed the finding of Vargas et al. (1999) and indicated that whereas calving ease might be advantageous in beef cattle management, it might limit profitability as it progressively reduced weaning weights in calves. Decreased milk production in primiparous cows also limited weaning weights of their calves

(Melton et al., 1967; Baker and Boyd, 2003). In the latter study, weaning weights of calves from 5- and 6-yr-old cows exceeded those of 2-yr-old cows by about 36 kg across 2 genetic lines.

Little is known about the effect of early weaning of cows on weaning weight of the subsequent calf. Most studies have been directed to its effects on weaning weight of the current calf with minimal attention to birth weight or weaning weight of the subsequent calf. Weaning weight of the subsequent calf is needed to fairly compare the producing ability of the cow because this measure is taken at the end of the period over which she exerts her maximum influence on growth of her calf.

Richardson et al. (1978) reported that BW gained by cows after weaning between 120 and 210 d postpartum was associated with increased calving difficulty the following year but did not affect BW of the subsequent calves. Pate et al. (1985) evaluated the effects of weaning calves at 8.5 vs. 10.5 mo of age on subsequent cow performance and obtained a 6.6 kg improvement in weaning weight of the subsequent calves by earlier weaning. That outcome was comparable with the 8.6-kg difference in the current study. Therefore, an early weaning age can offer significant productivity and possible economic advantages in cow-calf production.

Conclusions

Early weaning improved energy status and production efficiency in beef cows. The significant effects of age on BW, BCS, rib and rump fat, CI, BCI, and calf weaning weights demonstrate the importance that herd age profiles might have on the profitability of beef cattle enterprises. Based on the current work, calves from first and second parity cows should be weaned earlier than normal weaning of calves from older cows. Subjec-

tive discrepancies with utilizing BCS to predict energy status in beef cows might be minimized by ultrasonic measurement of rump fat. Therefore, further research is required to determine its use in nutritional management.

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