The impact of cow size on cow-calf and postweaning progeny performance in the Nebraska Sandhills

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ABSTRACT: Optimizing beef production system efficiency requires an understanding of genetic potential suitable for a given production environment. Therefore, the objective of this retrospective analysis was to determine the influence of cow body weight (BW) adjusted to a common body condition score (BCS) of 5 at weaning-influenced cow-calf performance and postweaning steer and heifer progeny performance. Data were collected at the Gudmundsen Sandhills Laboratory, Whitman, NE, on crossbred, mature cows (n = 1,607) from 2005 to 2017. Cow BCS at calving, prebreeding, and weaning were positively associated ($P < 0.01$) with greater cow BW. Increasing cow BW was positively associated ($P < 0.01$) with the percentage of cows that conceived during a 45-d breeding season. For every additional 100-kg increase in cow BW, calf BW increased ($P < 0.01$) at birth by 2.70 kg and adjusted 205-d weaning BW by 14.76 kg. Calf preweaning average daily gain (ADG) increased ($P < 0.01$) 0.06 kg/d for every additional 100-kg increase in cow BW. Heifer progeny BW increased ($P < 0.01$) postweaning with every additional 100-kg increase in dam BW. Dam BW did not influence ($P \geq 0.11$) heifer puberty status prior to breeding, overall pregnancy rates, or the percentage of heifers calving in the first 21 d of the calving season. Steer initial feedlot BW increased by 7.20 kg, reimplant BW increased by 10.47 kg, and final BW increased by 10.29 kg ($P \leq 0.01$) for every additional 100-kg increase in dam BW. However, steer feedlot ADG was not influenced ($P > 0.67$) by dam BW. Hot carcass weights of steers were increased ($P = 0.01$) by 6.48 kg with every additional 100-kg increase in cow BW. In a hypothetical model using the regression coefficients from this study, regardless of pricing method, cow-calf producers maximize the highest amount of profit by selecting smaller cows. Overall, larger-sized cows within this herd and production system of the current study had increased reproductive performance and offspring BW; however, total production output and economic returns would be potentially greater when utilizing smaller-sized cows.

Key words: cow size, heifer performance, production efficiency, steer performance

Transl. Anim. Sci. 2020.4:1-11
doi: 10.1093/tas/txaa194

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Received July 27, 2020.
Accepted October 20, 2020.

INTRODUCTION

In efforts to increase income, cow-calf producers have placed heavy selection pressure on growth traits to increase weaning and yearling weights (Lalman et al., 2019). Cow-calf producers that retain replacement females with increased growth potential may be increasing mature cow size as growth traits are highly heritable (Gosey, 2003). The influence of cow size on calf weaning weights varies depending on the production environment, management decisions, breed differences, and forage resources (Scasta et al., 2015; Beck et al., 2016; Bir et al., 2018; Williams et al., 2018). Buttram and Willham (1989) suggested smaller-framed cows that mature at an earlier age, and lighter body weight (BW) may be more favorable in limited-resource environments. Increasing cow size increases forage intake, which decreases the number of livestock that can be maintained in a fixed land base (Beck et al., 2016). Doye and Lalman (2011) estimated increasing cow size 45 kg increases feed cost by approximately $42 per cow to support the added forage intake associated with larger cows.

Increasing cow BW has been shown to be negatively correlated with the number of calves weaned (Stewart and Martin, 1981). Alternatively, smaller-framed cows may produce greater total kilograms weaned and increase gross revenue due to increased carrying capacity on fixed resources (Scasta et al., 2015; Beck et al., 2016; Bir et al., 2018). Previous research focused on how cow size impacts calf weaning weights but is limited in the number of animals evaluated and duration of the study (Scasta et al., 2015; Beck et al., 2016; Williams et al., 2018), simulated models (Notter et al., 1979), or lacked reproductive performance of the cowherd (Bir et al., 2018). The hypothesis of this study was that increased cow size in a semiarid environment could be detrimental to cow and heifer progeny reproductive performance but steer and heifer progeny may have increased preweaning and postweaning BWs. Therefore, the objectives of this research were to determine the impact of mature cow size on 1) preweaning calf growth and weaning weights and cow reproductive performance, 2) postweaning steer feedlot growth performance and carcass characteristics, 3) postweaning heifer progeny growth and reproductive performance, and 4) impact of cow size on the profitability of the cow-calf segment and retaining ownership of steer calves.

MATERIALS AND METHODS

The Institutional Animal Care and Use Committee at the University of Nebraska-Lincoln (IACUC approval number 1474) approved animal procedures and facilities used in this experiment.

Site Description

Warm-season grasses dominate upland range pastures at the University of Nebraska Gudmundsen Sandhills Laboratory (GSL), Whitman, NE. The primary plants on range pastures include little bluestem [*Andropogon scoparius* (Michx.) Nash], prairie sandreed [*Calamovilfa longifolia* (Hook.) Scribn.], sand bluestem (*Andropogon halli* Hack.), switchgrass (*Panicum virgatum* L.), sand lovegrass [*Eragrostis trichoides* (Nutt.) Wood], and blue grama [*Bouteoua gradis* (H.K.B.) Ex Griffiths]. Subirrigated meadows at GSL are dominated by cool season grasses, including slender wheatgrass [*Elymus trachycaulus* (Link) Matte], redtop bent (*Agrostis stolenifera* L.), timothy (*Phleum pretense* L.), Kentucky bluegrass (*Poa pratensis* L.), and smooth bromegrass (*Bromus inermus* Leyss.) (Griffin et al., 2012). Average annual precipitation at GSL from 2005 to 2017 was 54.09 cm with an SD of 16.60 cm. Upland, native range pastures at GSL were stocked at 0.6 animal unit months (AUM), whereas subirrigated meadows were stocked at 3.0 AUM.

Cow Management

Cow-calf data were collected from 2005 through 2017 at GSL. Cow performance data were obtained from both March- and May-calving herds at GSL to determine how cow size impacted cow, heifer, and steer progeny preweaning and postweaning performance. Cows in this study (*n* = 1,607) were Husker Red composites (5/8 Red Angus, 3/8 Simmental) ranging from 5 to 11 yr old (Table 1). Cows were at least 5 yr old or older to ensure that only mature cows were evaluated. Cow

Table 1. Mean, SD, range of cow BW, and age used to evaluate the impact of increasing cow BW by additional 100 kg impacts cow-calf performance

Measurement	Mean	SD	Minimum	Maximum
Cow BW, kg	501	50.6	292	793
March cow BW, kg	507	52.8	292	793
May cow BW, kg	477	49.7	306	638
Cow age, yr	6.5	1.5	5	11

BW and body condition score (BCS; 1 = emaciated, 9 = obese; Wagner et al., 1988) were collected at precalving, prebreeding, and at weaning. Cow BW collected at weaning was adjusted to a common BCS of 5 to standardize cow size. Cow BW was adjusted using equation:

$$SBW_5 = SBW/WAF_{BCS} \quad (1)$$

Where SBW_5 is the shrunk BW at BCS 5, kilograms; SBW is the shrunk BW at weaning, kilograms; and WAF_{BCS} is the weight adjustment factor (NASEM, 2016).

Bulls used for breeding were Husker Red composites (5/8 Red Angus, 3/8 Simmental) with moderate growth potential. The same bulls were used in both the March- and May-calving herds within each year. In all years, March-calving cows were exposed to fertile bulls starting in June of each year for a 45-d breeding season. In non-AI cows each year, estrus was synchronized with a single injection of prostaglandin $F_{2\alpha}$ (25 mg; Lutelyse; Zoetis Inc., Parisippany, NJ) after a 5-d exposure to fertile bulls (bull-to-cow ratio of 1:17). The May-calving herd was initiated in 2009. Each year, cows were exposed to fertile bulls in August for a 45-d breeding season. Approximately 45 d prior to breeding in each herd, cows received prebreeding vaccinations (Vista 5 VL5 SQ; Merck, Kenilworth, NJ). Each year, pregnancy diagnosis was determined approximately 75–110 d after the end of breeding season at weaning by transrectal ultrasonography.

Preweaning Calf Management

At birth, all calves received a seven-way clostridial vaccine (Alpha 7, Boehringer Ingelheim, Duluth, GA). At branding, calves were vaccinated for infectious bovine rhinotracheitis, bovine viral diarrhea types I and II, bovine parainfluenza virus-3, bovine respiratory syncytial virus, *Mannheimia haemolytica*, and *Pasteurella multocida* (Vista Once SQ, Merck, Kenilworth, NJ) and bull calves were castrated. A seven-way clostridial vaccine was also given at branding (Vision 7, Merck, Kenilworth, NJ). At weaning, all calves received one vaccination of Vista Once SQ and received a second dose 14 d later. A seven-way clostridial vaccine with somnus (Vision 7 Somnus, Merck, Kenilworth, NJ) was also given at weaning. Calf BW was measured at birth, prebreeding, and weaning each year. An adjusted 205-d BW was calculated without adjusting for cow age. March-born calves were weaned in September through December depending on forage availability. May-born calves were weaned in December or January each year.

Postweaning Steer Management

After weaning, March-born steers remained at GSL for 2 wk with ad libitum access to subirrigated meadow hay. Steers were then transported to the feedlot at the West Central Research and Extension Center, North Platte, NE. Over 54 d, steers were adapted to a common finishing diet of 48% dry-rolled corn, 7% prairie hay, 40% wet corn gluten feed, and 5% supplement (dry matter basis). Steers were implanted with 100 mg of trenbolone acetate and 14 mg estradiol benzoate (Synovex Choice; Ft. Dodge Animal Health, Overland, KS) upon feedlot entry. At approximately 100 d prior to harvest, steers received a second implant with 200 mg trenbolone acetate and 24 mg estradiol benzoate (Synovex Plus; Ft. Dodge Animal Health, Overland, KS).

After weaning, May-born steers grazed subirrigated meadow with 0.45 kg/d of a distillers-based protein supplement (33% CP and 78% TDN on a dry matter basis) or received ad libitum hay with 1.8 kg/d of the dried distillers-based supplement depending on the study steers were allotted to. May-born steers received Revalor G (Merck Animal Health, Summit, NJ) and grazed upland range pastures at GSL, then entered a feedlot at the West Central Research and Extension Center in mid-September. Upon feedlot entry in September, yearling steers were implanted with 36 mg Zeranol (Ralgro; Merck Animal Health, Summit, NJ). Steer BW was measured approximately 97 d prior to slaughter and steers were reimplanted with Synovex Plus (Ft. Dodge Animal Health, Overland, KS). May-born steers were adapted over 28 d to the same finishing diet as the March-born steers.

Upon feedlot entry, all steers were limit fed 5 d at 2.0% of BW and weighed two consecutive days for an average feedlot entry BW. Reimplant BW was collected on all steers prior to the morning feeding. Final BW was calculated for March- and May-born steers from hot carcass weight (HCW) adjusted to a common dressing percentage of 63% (Jolly-Breithaupt et al., 2018). Each year, within the different season of calving, steers were sent as a single group to a commercial processing facility (Tyson Fresh Meats, Lexington, NE) when backfat thickness (BF) was estimated to be 1.27 cm using visual appraisal. Carcass data were collected after a 24-hr chill period and included HCW, BF, marbling, yield grade (YG), and longissimus muscle area (LMA).

Postweaning Heifer Management

After weaning, heifers remained at GSL and were managed together within their respective breeding group. March-born heifers grazed subirrigated meadow pastures during the dormant season and were moved to upland range pastures in June prior to breeding. May-born heifers grazed upland range pastures continuously. Heifer BW was collected at weaning, prebreeding, pregnancy diagnosis, and prior to calving. Heifer BCS was also collected at pregnancy diagnosis and precalving by an experienced technician using visual appraisal and palpation. Heifer pubertal status was determined from two blood samples collected 10 d apart approximately 15 d prior to the breeding season. Heifers were exposed to bulls for a 45-d breeding season with a bull to heifer ratio of 1:20. The same bulls were used in both the March- and May-calving herds. Heifers were synchronized with a single injection of prostaglandin $F_{2\alpha}$ (5-mL i.m.; Lutalyse, Zoetis, Parisippany, NJ) 5 d after bulls were introduced in the pasture for breeding. Pregnancy diagnosis was conducted 40 d after the breeding season via transrectal ultrasonography (ReproScan, Beaverton, OR). The percentage of heifers calving within the first 21 d of calving was calculated after 2 or more heifers had calved.

Hypothetical System Output Model

A hypothetical partial budget was built to evaluate the producer-level financial impacts of increasing cow size by 100 kg. Two separate herds are assumed, one consisting of small-sized (454 kg) cows and one large-sized cows (554 kg). Performance parameters of cow progeny by dam weight were calculated from previously estimated equations.

The hypothetical partial budget compared small and large cows on a 2,023-ha ranch in the Nebraska Sandhills providing 0.5 AUM/ha for annual grazing. Thus, a total of 156 and 136 cow–calf pairs could be maintained in the assumed ranch by small- and large-sized cow herd, respectively. Sex of calf distribution of the calf crop was estimated at 50% for each sex. A 15% heifer replacement rate was assumed to maintain herd numbers.

A representative Nebraska Sandhills cow-calf producer was assumed to be trying to maximize profit by choosing dam size subject to fixed production costs and input and output price uncertainty. Cow-calf revenue is generated by selling weaned calves and cull cows. Primary costs are pasture rent, other feed costs, and other cow costs. Calf prices were estimated using an average price for steers and heifers over a 10-yr period combined from auctions in Nebraska (LMIC, 2020). Pasture lease rates were obtained from the University of Nebraska Farm Real Estate Market Survey for the North region of Nebraska on average quality pastures and averaged over 5 yr ($60.29/ha; Nebraska Farm Real Estate Reports). A bull-to-cow ratio of 1:25 was assumed for both herds, and bull purchase price was assumed at $3,000/bull.

The producer has the option to retain the ownership of unsold weaned calves into the feedlot and sell fat cattle. Retained calves in the feedlot are subject to daily per head yardage costs, feed costs, and miscellaneous costs. Total production profit is the combination of both sectors and written as:

$$\pi_{(\text{dam weight})} = \sum_{p=1}^{P} \left(\sum_{k=1}^{K} \mathrm{TR}_k^p - \mathrm{TC}_k^p + \sum_{m=1}^{M} \mathrm{TR}_m^p - \mathrm{TC}_m^p \right) \tag{2}$$

where p is the number of operational phases where $P = \{\textbf{cow} - \textbf{calf},\ \text{feedlot}\}$, TR_k^p and TR_m^p are total revenues associated with output k and output m in production-phase cow-calf and feedlot respectively, TC_k^p and TC_m^p is the total cost associated with output k and output m in production-phase cow-calf and feedlot respectively, $\mathrm{TR}_k^p - \mathrm{TC}_k^p$ is net profit from cow-calf production for k outputs where $K = \{\textbf{heifers},\ \text{cull cows}\}$, and $\mathrm{TR}_m^p - \mathrm{TC}_m^p$ is the net profit from feedlot production for outputs m where $M = \{\textbf{steers}\}$. The analysis assumed that all heifers not retained are sold in the cash market, with 10% cow culling rate in herds with smaller cows and 4% cow culling rate in herds with larger cows, which was calculated by the pregnancy rates of those herds. All steer calves are assumed to be weaned and retained into feedlots and sold as fat cattle.

Statistical Analysis

All analyses were performed using SAS 9.4 PROC GLIMMIX (SAS, Cary, NC). A similar model was used to analyze both the cow and progeny performance data. To account for differences in calving season (March or May) and differences among years, a SEASONYR term was determined. The initial model included the fixed effects of linear-adjusted cow BW at weaning, linear calf birth weight, and linear calf Julian birth date and the random effects of adjusted cow BW by SEASONYR, linear calf birth weight by SEASONYR, and calf birth date by SEASONYR and residual error. In order to account for the differences between seasons and among years, the error term used for testing the linear-adjusted cow BW effect was the adjusted cow BW by SEASONYR random effect; the error term used for testing the linear calf birth weight effect was the calf birth weight by SEASONYR random effect; and the error term used for testing the linear calf birth date effect was the calf birth date by SEASONYR random effect. Nonsignificant calf birth weight and birth date terms ($P > 0.05$) were dropped to produce the final model. A normal distribution was assumed for all measures, except for cow pregnancy rate, heifer pubertal status, heifer pregnancy rate, and 21-d calving interval where a binomial distribution was assumed. Binomial data was evaluated using the odds and odds ratio. Odds (*0*) were the probability (*P*) of the event occurring over the event not occurring ($1 - P$). Odds ratio is the ratio of the odds for two different levels. When evaluating the influence of adjusted cow BW at weaning on the pubertal status of heifer progeny, the linear effect of heifer birth date would not converge, so it was not included in the analysis. Significance was determined at $P \leq 0.05$.

RESULTS AND DISCUSSION

Cow Performance

Table 1 contains the average demographics of cows included in the retrospective analysis. The average-adjusted cow BW over the 13-yr period was 501 ± 50.6 kg and ranged from 292 to 793 kg. Olson et al. (2011) estimated the average cow BW of popular U.S. beef breeds to be 630 kg in 2009. In agreement, McMurry (2008) determined that cow mature BW in the United States has increased from 477 to 614 kg from 1975 to 2009. Based on data from the USDA National Agriculture Statistics Service (2019), slaughter cow HCW have increased 16 kg since 2009. Therefore, it is likely that the national mature cow size has increased since 2009 and this study contains cows smaller than the current national average cow size.

Cow BCS and BW precalving, prebreeding, and at weaning were positively associated ($P < 0.01$, Table 2) with increased adjusted cow BW. Cow BW change from precalving to weaning increased (20.8 kg, $P < 0.01$) with every additional 100-kg increase in cow BW, which may be due to the increased rumen capacity and ability to consume more forage by larger cows; for instance, Wiseman et al. (2018), where an additional 600 kg of forage was required for every additional 100 kg of cow BW.

Cow pregnancy rates in the current study were positively influenced ($P < 0.01$; Table 2) with increasing cow BW. Using regression coefficients in Table 2, smaller (454 kg) cows were estimated to have 90% pregnancy rates (odds of being pregnant 9.32) whereas larger (554 kg) cows were estimated to have 96% pregnancy rates (odds of being pregnant 24.06). So, the odds of being pregnant at 554 kg is 2.57 times greater than the odds of being pregnant at 454 kg. This could be attributed to the inability of small-sized cows to maintain BW from precalving to weaning, which would indicate that energy stores are used to compensate for dietary deficiencies. The ability for larger cows in the current data set to gain BW more quickly after calving may have positively influenced pregnancy rates. In contrast to this study, Beck et al. (2016) reported that cow BW did not influence the pregnancy rates of cows grazing improved pastures. In this study, cow pregnancy rate increased as cow size increased. However, the data set contained smaller cows compared with the current national average cow size. Larger cows than the ones evaluated in the current analysis may yield different results in limited nutrient environments.

Table 2. Regression coefficients used to evaluate the impact of increasing cow BW by additional 100 kg impacts cow performance

Measurement	Estimate	SEM	*P*-value
BW, kg			
Precalving	90.1	1.87	<0.01
Prebreeding	92.2	2.01	<0.01
Weaning	111.0	0.88	<0.01
BW change[a]	20.8	1.75	<0.01
BCS			
Precalving	0.41	0.03	<0.01
Prebreeding	0.42	0.02	<0.01
Weaning	0.35	0.03	<0.01
	Odds ratio[b]	99% CI	
Pregnancy rate	2.57	(1.412, 4.753)	<0.01

[a]Precalving to weaning.

[b]Odds of being pregnant at 554 kg over the odds of being pregnant at 454 kg.

Calf Preweaning Performance

For every additional 100-kg increase in cow BW, calf BW at birth increased by 2.65 kg ($P < 0.01$; Table 3). Stewart and Martin (1981) reported an increase of 4.8 kg in calf BW at birth for every 100-kg increase in cow BW. Calf-adjusted 205-d weights increased ($P < 0.01$) by 14.54 kg for every 100-kg increase in cow BW. This increase in calf BW at weaning was partially due to differences in preweaning average daily gain (ADG). Preweaning ADG increased ($P < 0.01$) by 0.06 kg/d for every 100-kg increase in cow BW. In a more humid environment, Beck et al. (2016) reported a 19-kg increase in calf BW at weaning for each 100-kg increase in cow BW. Bir et al. (2018) reported that a 100-kg increase in cow BW increased calf BW at weaning by 7 kg. The contrasting responses in calf BW at weaning among the studies could be attributed to forage quality and quantity, environmental conditions, and breed/genetic selection differences, although the impact of cow size on calf weaning weights may be more pronounced in more temperate climates with improved pastures (Beck et al., 2016). Scasta et al. (2015) evaluated the drought gradient across 4 yr on cow size and calf weaning weights. Results indicated as precipitation patterns change, the optimal cow size for maximum weaning BW also changes (Scasta et al., 2015). Our data was collected over a 13-yr period, so the variation in calf weaning weights due to environmental factors by year is likely reduced. The ratio of calf BW at weaning to cow BW at weaning decreased by 0.08 kg ($P < 0.01$; Table 3) for every 100-kg increase in cow BW. In agreement, smaller cows have shown to demonstrate a greater percentage of BW weaned compared with larger cows (Scasta et al., 2015).

Heifer Postweaning Performance

After weaning, heifer BW increased through calving as a first-calf heifer ($P < 0.01$; Table 4) for every additional 100-kg increase in dam BW. In addition, heifer BCS at pregnancy diagnosis was increased 0.05 BCS ($P < 0.04$, Table 4) with an additional 100-kg increase in dam BW. Although BCS increased in heifers produced by larger dams, the biological relevance of the increased BCS at pregnancy diagnosis is minimal due to the small numerical increase. Heifer BCS measured prior to calving was not ($P = 0.91$) affected by dam BW. This may be due to changes in forage quality while grazing dormant pastures postweaning and the ability for small-framed heifers to gain condition more easily compared with larger heifers (Vargas et al., 1999).

In the current study, heifer puberty attainment prior to the breeding season was not influenced ($P = 0.99$; Table 5) by increasing dam BW. Converting the regression coefficients related to heifer reproductive performance into scale of measure is reported in Table 5. The likelihood of heifers achieving puberty prior to the breeding season was not influenced ($P = 0.99$) by dam BW. In contrast to the current study, Short and Bellows (1971) reported a greater number of heifers reaching puberty as BW increased linearly. In a review, Patterson et al. (1992) suggested that heifers with greater BW at 6 mo of age reach puberty at younger

Table 3. Regression coefficients for the impact of increasing cow BW by 100 kg on calf preweaning performance

Measurement	Estimate	SEM	*P*-value
BW, kg			
Birth	2.65	0.23	<0.01
Adjusted 205 d	14.54	1.13	<0.01
WW ratio[a]	−0.08	0.003	<0.01
ADG, kg/d			
Birth to weaning	0.06	0.005	<0.01

[a]Kilogram of calf weaned divided by unadjusted cow BW at weaning.

Table 4. Regression coefficients used to evaluate the influence of increasing dam BW 100 kg on heifer progeny postweaning performance

Measurement	Estimate	SEM	*P*-value
BW, kg			
Postweaning	9.32	1.67	<0.01
Prebreeding[a]	11.00	2.20	<0.01
Pregnancy check	13.10	2.11	<0.01
Precalving	13.17	2.83	<0.01
BCS[b]			
Pregnancy check	0.05	0.02	0.04
Precalving	0.002	0.04	0.96

[a]Prebreeding weights were collected approximately 15 d prior to breeding in June or August according to calving season.

[b]BCS of 1 (emaciated) to 9 (obese; Wagner et al., 1988).

Table 5. Regression coefficients used to evaluate the influence of increasing dam BW 100 kg on heifer progeny reproductive performance

Measurement	Odds ratio[a]	95% CI	*P*-value
Pubertal status	0.999	(0.640, 1.5594)	0.99
Pregnancy rate	0.691	(0.440, 1.085)	0.11
Calving first 21 d	1.022	(0.633, 1.666)	0.93

[a]Odds of a positive status (pubertal, pregnant, and calved in the first 21 d) in daughters from 554-kg dams over the odds of a positive status for daughters from 454-kg dams.

ages and lead to heavier BW at first calving. In contrast, Vargas et al. (1999) reported that small- and medium-framed heifers achieved puberty at a younger age than large-framed heifers. Our data suggest that dam BW and growth differences in heifer progeny did not influence heifer progeny prebreeding puberty status. The current study suggests that dam BW and growth differences did not influence heifer pregnancy rates ($P = 0.11$; Table 5) or the number of heifers calving in the first 21-d of the calving season ($P = 0.93$; Table 5). In agreement with our results, Vargas (1999) reported no difference in calving date or calving rate between small-, medium-, or large-framed first-parity heifers.

Steer Postweaning Performance

Steer feedlot entry BW, reimplant BW, and final live BW increased ($P \leq 0.04$; Table 6) with every additional 100-kg increase of dam BW. However, feedlot ADG was not influenced ($P \geq 0.33$) by dam BW. In agreement, Olson et al. (1982) reported that cow size influenced steer progeny BW at the start of the backgrounding phase and steer final live BW with no differences in ADG. In contrast, Smith (1979) suggested that large, late-maturing breeds gained more rapidly in the feedlot and were more efficient than small-framed cattle.

Steer HCW increased ($P = 0.01$; Table 7) by 6.51 kg for every additional 100-kg increase of cow BW. In agreement, Olson et al. (1982) reported increased HCW of steers from small- to large-sized dams. Marbling score in the current study tended ($P = 0.07$) to increase 0.14 for every

Table 6. Regression coefficients used for estimating the influence of 100-kg increase of cow BW on steer progeny feedlot performance

Measurement	Estimate[a]	SEM	*P*-value
BW, kg			
Entry	7.20	3.12	0.04
Reimplant	10.47	3.51	0.01
Final live weight[b]	10.33	3.61	0.01
ADG, kg/d			
Beginning[c]	−0.07	0.07	0.33
Ending[d]	0.03	0.04	0.45
Total[e]	0.008	0.02	0.67

[a]Regression coefficient used to evaluate increasing cow size on steer progeny.

[b]Final live weight was calculated using HCW adjusted to a common dressing percentage of 63%.

[c]ADG from feedlot entry to reimplant.

[d]ADG from reimplant to slaughter.

[e]ADG throughout the feeding period.

Table 7. Regression coefficients used to estimate the influence of increasing cow BW 100 kg on steer progeny carcass performance

Measurement	Estimate	SEM	*P*-value
HCW, kg	6.51	2.26	0.01
Marbling[a]	0.14	0.07	0.06
Backfat, cm	0.003	0.0001	0.97
Yield grade	0.0004	0.0005	0.52
LMA, cm^2	0.0002	0.001	0.83

[a]Marbling Score System: 400 = Small00.

additional 100-kg increase in cow BW. In contrast, Olson et al. (1982) reported similar marbling scores of steers from different size cows. Nephawe et al. (2004) reported the genetic correlation between mature cow BW and marbling scores of steer progeny to be negative and suggested that the selection for smaller cows would slowly increase marbling in progeny. Backfat, YG, and LMA were not influenced ($P \geq 0.47$) by dam BW in this study. The genetic correlation between mature cow BW and steer progeny LMA was reported to be low to moderate (Nephawe et al., 2004), which may explain why cow BW did not influence steer LMA in the current study.

Cow Size Hypothetical Model

Total output (calf weaning BW and cull cow BW) was estimated based on the regression coefficient estimates in a hypothetical scenario assuming two separate herds consisting of small-sized (454 kg) and large-sized cows (554 kg) relative to the current data set (Table 8). A total of 156 and 136 cow–calf pairs could be maintained in the assumed pasture (2,023 ha) for small- and large-sized cows, respectively. When considering the offspring BW and cull cow BW, total output at weaning was 4,162 kg greater in the small-sized cow herd compared with large-sized cow herd. If steer calves were retained postweaning through the finishing phase, the number of steers produced in the small-sized cow herd produced an additional 3,894 kg of steer HCW compared with the large-sized cowherd. The increase in total kilograms produced at weaning and after the feedlot phase is driven by increased carrying capacity in smaller-sized cows.

Table 9 reports performance parameters, market assumptions, and necessary calculations used to obtain total revenue, total cost, and net profit for each operational phase in both herds with small and large cows. Herds with smaller cows produce more calves that are lighter, resulting in lower

Table 8. Total output (kilograms) estimated using small (454 kg) and large (554 kg) cows using recommended stocking rates for a 2,023-ha ranch in the Nebraska Sandhills

Measurement	Small cow	Large cow	Source
Cow-calf production			
Calf crop			
Cow-calf pairs, *n*	156	136	Stocking density given 2,2023 ha
Cow pregnancy rate, %	90	96	Table 2
Total calves, *n*	156	136	Assumed from stocking density
Heifer retention rate, %	15	15	Average retention rate
Heifers sold at weaning	55	58	*n* of heifers × retention rate
Heifer weaning weight, kg	204	218	Table 3
Steers to retain into feedlot, *n*	78	68	Half of calf crop
Steer weaning weight, kg	216	231	Table 3
Total heifer output, kg	11,220	12,644	*n* of heifers sold × heifer weaning weight
Total steer output, kg	16,848		×steer weaning weight
Cull cows			
Cull cow rate, %	10	4	% open cows in Table 2
Cull cows sold	16	5	Cow-calf pairs × cull rate
Cull cow weight, lb.	454	545	Assumed dam weight in each herd
Total cull cow output, kg	7,264	2,725	Cull cows sold × cull weight
Total cow-calf output, kg	35,332	31,077	Steer output + heifer output + cull cow output
Total cow-calf output sold[a], kg	18,484	15,369	Heifer output + cull cow output
Feedlot production			
Retaining ownership[a]			
Steer HCW, kg	437	444	Table 7
Total feedlot output, kg	34,086	30,192	HCW × *n* of steers sold

[a]Assumes all steers progeny are held for retained ownership into feedlots.

gross revenue from heifer sales compared to herds with larger cows. Herds with smaller cows cull a larger share of the herd each year, resulting in relatively more cull cow gross revenue. Total costs to run a smaller cow were larger due to added fixed costs of running another cow–calf pair (i.e., veterinary costs, labor, and interest). If only heifers and cull cows were sold in the cash market, smaller cows were relatively more profitable than larger cows on a per-cow basis. Cow-calf operators would lose approximately $811 per small cow and $897 per large cow. If steers were also sold in the cash market at weaning, then cow-calf operators would lose approximately $393 per small cow and $468 per large cow. Total costs were larger for herds with smaller cows, but those costs were spread across more cow–calf pairs.

Revenue, costs, and net profit for retaining steers into a custom feedlot impacted cow-calf producer profitability. Tables 6 and 7 suggest that dam weight significantly affects progeny feedlot performance, yield, and quality grading characteristics. On average, progeny from smaller cows perform and grade relatively better than progeny from larger cows. Total feedlot costs were larger for herds with smaller cows due to more days on feed and more steers being fattened. Grid pricing captures the relative carcass performance of each finished steer by assigning premiums and discounts to a set base (dressed wt.) price. If a cow-calf producer were to sell on the grid, net profit would be approximately $1,196 per steer for steers from smaller cows and $1,229 from larger cows. More steers were finished from herds that have smaller cows. Overall, the net profit difference between herds with small and large cows was $9,719 under grid pricing. Finished cattle in Nebraska are generally sold either on a negotiated cash live weight basis or formula/grid pricing on a dressed basis. If finished steers were sold on a live weight basis, then overall profit would be lower regardless of cow size. The overall net profit difference between herds with small and large cows was $7,448. Total operational profit is obtained by combining net profit from the cow-calf and feedlot operation either live or dressed. Regardless of pricing method, cow-calf producers maximize the highest amount of profit by selecting smaller cows. Overall net profit for cow-calf producers using grid (live) pricing was −$212 (−$340) for operations with

Table 9. Partial budget analysis used to evaluate net revenue generated from small (454 kg) and large (554 kg) cows using recommended stocking rates in the Nebraska Sandhills

Measurement	Small cow	Large cow	Source
Cow-calf production			
Revenue			
Total heifer output, kg	11,220	12,644	Table 8
Heifer cash price, $/kg	3.704	3.549	Average NE prices from 2005–2017, LMIC (2020)
Total heifer revenue, $	41,556	44,879	**Heifer** output × heifer price
Cull cow output, kg	7,264	2,725	Table 8
Cull cow price, $/kg	1.518	1.535	Average cull cow prices from 2005–2017, LMIC (2020)
Total cull cow revenue, $	11,027	4,184	**Cull** cow output × cull cow price
Total cow-calf revenue, $	52,584	49,063	Heifer revenue + cow-calf revenue
Costs			
Number of bulls, *n*	6	5	~25:1 cow:bull ratio
Price per bull, $	3,000	3,000	Average price paid for bulls at GSL
Total bull cost, $	18,000	15,000	***n* of bulls** × **price** per bull
Pasture, $/ha	60.29	60.29	Nebraska Farm Real Estate reports
Pasture, ha	2,023	2,023	Average ranch size in Nebraska
Total grazing/feed cost, $	121,967	121,967	**Pasture** land × **rental** rate
Misc. cow costs, $/cow	251	251	Total cow costs per year − feed and pasture costs (FINBIN 2020)
Total misc. costs, $	39,156	34,136	**Cow** − **calf** pairs × misc. cow costs
Total cow-calf costs, $	179,123	171,103	Bull cost + grazing cost + misc. cost
Net profit cow-calf production			
Profit, $	−126,539	−122,040	Cow-calf revenue − cow-calf costs
Profit, $/cow	−811.15	−897.35	Profit/cow–calf pair
Feedlot production			
Revenue			
HCW, kg	437	444	Table 7
YG, 1–5	2.800	2.800	Table 7
Marbling	500.230	500.350	Table 7
QG	Choice	Choice	Table 7
Grid premiums, $/kg	0.048	0.048	Average premiums from 2005–2017, LMIC (2020)
Grid discounts, $/kg	0.005	0.005	Average discounts from 2005–2017, LMIC (2020)
Price dressed wt., $/kg	3.891	3.891	Average dressed wt. price from 2005–2017, LMIC (2020)
Price live wt., $/kg	2.456	2.456	Average live wt. price from 2005–2017, LMIC (2020)
Total steer revenue (grid), $	134,114.28	118,793.00	(**Price** dressed+Premiums − **Discounts**) × HCW × *n* of **steers**
Total steer revenue (live wt.), $	114,234.37	101,184.19	**Price** live × HCW × 1.**37** × *n* steers
Costs			
Yardage costs, $/hd/d	0.5	0.5	Industry average in Nebraska
Days on feed, d	240	237	(**HCW** × **1.37** − **Steer** weaning weight)/ADG
Total yardage costs, $	9360	8058	***n* of steers** × days on feed × yardage cost
ADG, kg/d	1.642	1.647	Table 7
Feed conversion, kg of feed: kg of gain	6.0	6.0	Industry average in Nebraska
Feed intake, kg/hd	2,364.49	2,341.38	**Feed** conversion × ADG × days on feed
Ration costs, $/kg	0.17	0.17	Industry average in Nebraska
Total feed costs, $	30,494.88	26,325.49	**Feed** intake × ration cost × ***n* of steers**
Misc. costs, $/hd/d	0.05	0.05	Accounts for vet costs, labor, interest, etc. (Expert opinion)
Total misc. costs, $	936.00	805.80	**Misc**. costs × ***n* of steers**
Total feedlot costs, $	40,790.88	35,189.29	Yardage cost + feed cost + misc. cost
Net profit feedlot production			
Profit (live), $	73,443.49	65,994.90	**Total** steer revenue (**live**) − total feedlot costs
Profit (live), $/hd	941.58	970.51	Profit (live)/*n* of steers
Profit (grid), $	93,323.40	83,603.71	**Total** steer revenue (**grid**) − total feedlot costs
Profit (grid), $/hd	1,196.45	1,229.47	Profit (grid)/*n* of steers
Operational net profit			
Net profit (live), $	−53,095.48	−56,044.99	Cow-calf net profit + feedlot net profit (live)

Table 9. Continued

Measurement	Small cow	Large cow	Source
Net profit (live), $/cow	−340.36	−412.10	[Net profit (live)]/cow–calf pairs
Net profit (grid), $	−33,215.58	−38,436.17	Cow-calf net profit + feedlot net profit (grid)
Net profit (grid), $/cow	−212.92	−282.62	[Net profit (grid)]/cow–calf pairs
Net profit (no feedlot), $	−61,393.10	−63,656.88	Cow-calf net profit + (*n* of steers × weaning weight × 3.86)
Net profit (no feedlot), $/cow	−393.55	−468.07	Net profit (no feedlot)/cow–calf pairs

smaller cows and −$282 (−$412) for operations with larger cows.

Conflict of interest statement. The authors declare no conflicts of interest that may influence this work.

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