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Production performance of cows raised with different postweaning growth patterns

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ABSTRACT: The period of heifer development is a relatively small fraction of a cow's life; however, her pattern of growth may have permanent effects on her productivity as a cow. We hypothesized that altering the growth pattern during the peri-pubertal period would increase life-time productivity across genetic types of *Bos taurus* cows. The objective was to determine the stayability, calf production, and weight of calf weaned across six calf crops. Heifers (n = 685) were placed on one of two developmental programs at 256 ± 1 d of age. Control heifers received a diet that provided 228 kcal ME·(body weight [BW], kg) $^{-0.75}$ daily, and stair-step heifers were allocated 157 kcal ME·(BW, kg)$^{-0.75}$ daily for 84 or 85 d, and then the daily allocation was increased to 277 kcal ME·(BW, kg)$^{-0.75}$. Stair-step heifers (0.33 ± 0.02 kg/d) had a lower average daily gain (ADG) than control heifers (0.78 ± 0.02 kg/d; $P < 0.001$) during Period 1, and stair-step heifers (0.93 ± 0.03 kg/d) had a greater ADG than controls (0.70 ± 0.03 kg/d; $P < 0.001$) during Period 2. There were no treatment ($P = 0.28$) or breed type differences ($P = 0.42$) for the proportion of cows weaning a calf; however, the proportion of cows weaning a calf decreased with cow age ($P < 0.001$). Calves from stair-step dams had heavier weaning weights (193 ± 1 kg) compared to control calves (191 ± 1 kg; $P = 0.007$). There was not a treatment ($P = 0.25$) or breed type differences in cumulative BW weaned ($P = 0.59$). A diverse genetic population of cattle within *B. taurus* was tested and responses in calf production did not differ between stair-step growth pattern and a more constant nonobese growth pattern.

Key words: development, heifer, production

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INTRODUCTION

Replacing cows in the herd is a primary cost associated with beef production. Typically, 15% to 20% of the cows are replaced annually. High female replacement rates reduce the number of calves sold. Decreasing the rate that cows are culled from the herd would reduce replacement rates. Inadequate nutrition (Jourbert, 1954; Wiltbank et al., 1969; Ferrell, 1982) and overnutrition (Pinney et al., 1972) during heifer development can have negative impacts on retention. Malnutrition during heifer development has been associated with permanent changes in milk production (Ferrell, 1982; Johnsson and Obst, 1984; Park et al., 1998). Several studies have been conducted to determine the efficacy of manipulating heifer growth rate through nutrition to improve cow retention and weight of calf weaned. These studies have typically either developed heifers to a lighter body weight (BW) at breeding (Freetly and Cundiff, 1997, 1998; Freetly et al., 2001; Roberts et al., 2009) or a stair-step protocol that limits growth early followed by a rapid rate of BW gain (Clanton et al., 1983; Lynch et al., 1997; Grings et al., 1999, Freetly et al., 2001). A few studies have followed cows through their third parity (Funston and Deutsher, 2004; Lardner et al., 2014); however, most have been limited in scope and evaluated cows only through their first parity. With the exception of Grings et al. (1999) and Roberts et al. (2009), most of the studies

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concentrated on cattle that were predominantly British in their genetic type. We hypothesized that altering the growth pattern during the peri-pubertal period would increase life-time productivity across genetic types of *Bos taurus* cows. The objective was to determine the stayability, calf production, and weight of calf weaned across six calf crops.

MATERIALS AND METHODS

Cattle

Research protocols were approved and monitored by the USDA, ARS, U.S. Meat Animal Research Center Institutional and Animal Care Committee in accordance with the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999).

Heifers (n = 685) from three composites lines (MARC I, n = 153; MARC II, n = 170; and MARC III, n = 187) and Angus (n = 175) were developed in two nutrition treatments. The three composite lines consisted of different proportions if British and Continental types of cattle: MARC I (25% Braunvieh, 25% Charolais, 25% Limousin, 12.5%, MARC II (Gelbvieh, 25% Simmental, 25% Hereford, and 25% Angus), and MARC III (25% Pinzgauer, 25% Red Poll, 25% Hereford, and 25% Angus). Heifers were placed on the study at 256 ± 1 d of age. Prestudy management was the same across treatments and breed types within a year, and it was similar across years. The study was conducted over a 6-yr period. MARC I were developed in yr 1 through 3, MARC II were developed in yr 2 through 4, Angus were developed in yr 3 through 5, and MARC III were developed in yr 4 through 6. These populations were concurrently used to evaluate combinations of genetic markers putatively associated with carcass and meat traits in steers (Bennett et al., 2013; Tait, Jr., et al., 2014a, 2014b; Bennett et al., 2019). Cows were subsequently evaluated for six calf crops.

Cattle Management and Nutrition Treatment

Each year heifers were stratified into two herds per breed type (21 to 34 heifers/herd) based on sires, breed types, genetic markers, and age. These herds were then randomly assigned to receive either the stair-step or control treatment such that there was one herd in each treatment. Heifers were fed a ration that as dry matter consisted of 69.8% corn silage, 30.0% ground alfalfa hay, and 0.2% salt. Control heifers were allocated to receive 228 kcal ME·(BW, kg)$^{-0.75}$ daily, and stair-step heifers were allocated 157 kcal ME·(BW, kg)$^{-0.75}$ daily. Feed allocation was adjusted weekly for changes in BW. BW was measured every 2 wk and feed allocation for the interim week was calculated based on estimated BW gain between measured weights. Stair-step heifers remained on this feeding level for 84 or 85 d, and then the daily allocation was increased to 277 kcal ME·(BW, kg)$^{-0.75}$ over an 18-d transition period. Heifers were fed at this level for an additional 62, 60, 31, 44, 45, or 44 d depending on the year. The increase in feed intake began 71 to 88 d before breeding depending on the year.

The first 2 yr, heifers were determined to have reached puberty based on behavioral estrous. In subsequent years, the presence of a corpus luteum on ovaries was determined by ultrasonography. Presence of a corpus luteum was determined in March, April, and May. Heifers that had a corpus luteum were determined to be pubertal.

Heifers/cows were bred to bulls of the same breed type. Cows were given the opportunity to wean six calves. Cows that were not diagnosed pregnant at palpation were removed from the study after weaning their calf. Cows with physical or medical abnormalities were removed from the study. Cows were weighed in June before breeding. Calves born to the cows were weighed at birth and weaning.

Data Analysis

Data from the growing period were analyzed with the Mixed Procedure in SAS (Cary, NC). The models included treatment, breed type, year, and the interaction of treatment by breed type with the denominator degrees of freedom set to the Kenward−Roger method. The following were treated as random: herd nested in treatment by breed type, herd nested in the year, and year nested within breed type. Herd is considered the experimental unit.

The percent heifers pubertal before breeding were analyzed using the GLIMMIX procedure in SAS (Cary, NC). The model included fixed effects for treatment, breed type, and the interaction treatment by breed type. Herd within treatment by breed type was random. The data were analyzed as binomial with a logit link. Cows that calved as 2-yr-olds were analyzed using the same model and also included the fixed effect of whether or not they had reached puberty before breeding and the two-way interactions with treatment and breed types. Herd is considered the experimental unit in both analyses.

Cow BW at breeding was analyzed in the Mixed Procedure in SAS (Cary, NC). The models included treatment, breed type, cow age and all the two-way interactions with the denominator degrees of freedom set to the Kenward−Roger method. The following were treated as random: herd nested in year, and year nested within breed type. Cow age was considered as repeated with the subject equal to herd nested in treatment by breed type. Herd is considered the experimental unit.

The proportion of cows weaning a calf was analyzed in the GLMIX Procedure in SAS (Cary, NC). The model included treatment, breed type, cow age, treatment by breed type, treatment by cow age, breed type by cow age with the denominator degrees of freedom set to the Kenward–Roger method. Cow age was considered as repeated with the subject equal to herd nested in treatment by breed type. The data were analyzed as binomial with a logit. Herd is considered the experimental unit.

Weaning weight of calves was analyzed in the Mixed Procedure in SAS (Cary, NC). The model included treatment, breed type, cow age, calf sex, and the interactions of treatment by breed type, treatment by cow age, and breed type by cow age as fixed effects and calf age at weaning as a covariate. The denominator degrees of freedom set to the Kenward–Roger method. The following were treated as random: Herd nested in year, and year nested within breed type. Cow age was considered as repeated with the subject equal to herd nested in treatment by breed type. Herd is considered the experimental unit.

The cumulative BW weaned was analyzed in the Mixed Procedure in SAS (Cary, NC). The model included treatment, breed type and treatment by breed type with the denominator degrees of freedom set to the Kenward–Roger method. The following were treated as Random: Herd nested in year, year nested within breed type, and herd nested within treatment by breed type. Cow age was considered as repeated with the subject equal to herd nested in treatment by breed type. Herd is considered the experimental unit.

Treatment differences for the rate heifers were removed from the study were analyzed by calculating the fraction of heifers remaining in a herd from 1 through 6 yr of age and fitting the data to the function $f(\text{breeding age}) = 100e^{(k(\text{breeding age} - 1))}$ using NLIN Procedure in SAS (Cary, NC). An F-ratio was calculated to test whether treatment specific curves fit the data better than a pooled curve. The test statistic was

$$F = \frac{(RSS_P - RSS_S - RSS_C)/(Rdf_P - Rdf_S - Rdf_C)}{(RSS_S + RSS_C)/(Rdf_S + Rdf_C)}$$

where RSS represents residual sums of squares and Rdf denotes residual degrees of freedom; the subscripts P, S, and C indicate pooled, stair-step, and control, respectively. Large values of F provide evidence that the pooled, single model is inappropriate and that a treatment specific model fits the data better.

RESULTS

Body weight gain during the developing period and puberty are presented in Table 1. Treatments did not differ in age (P = 0.74) or initial BW (P = 0.58) at the start of the study. The MARC II heifers tended to be younger than Angus when they went on the study. MARC I (P = 0.03) and MARC III (P = 0.008) heifers were lighter than Angus heifers at the start of the study. Stair-step heifers had a lower average daily gain (ADG) than control heifers during Period 1 (P < 0.001), and stair-step heifers had a greater ADG during Period 2 (P < 0.001). Breed types did not differ in Period 1 ADG (P = 0.38) or Period 2 ADG (P = 0.93). Control heifers were heavier at the end of the feeding period than stair-step heifers (P = < 0.001). Treatment did not affect percent pubertal before breeding (P = 0.24). Fewer Angus were diagnosed pubertal before breeding than the other breed types (P < 0.04). Fewer cows that had not reached puberty before breeding (75.5 ± 6.2%) calved as 2-yr-olds when compared to cows that had reached puberty before breeding (88.7 ± 1.4%; P = 0.008).

Stair-step heifers were lighter at breeding than control heifers (P < 0.001); however, there were no treatment differences in subsequent years (Figure 1). There were no treatment (P = 0.28) or breed type differences (P = 0.42) for the proportion of cows weaning a calf; however, the proportion of cows weaning a calf decreased with cow age (P < 0.001; Table 2). Calves from stair-step dams had heavier weaning weights (193 ± 1 kg) compared to control calves (191 ± 1 kg; P = 0.007. The interactions for cow treatment and breed type (P = 0.99) and treatment and cow age did not differ (P = 0.23; Table 2). There was not a treatment (P = 0.25) or breed type difference in cumulative BW weaned (P = 0.59; Figure 2). Treatment specific decay curves for the fraction of original cows present at breeding fit the data better than a pooled curve (Figure 3).

DISCUSSION

Calving cows with their first calf as 2-yr-olds rather than 3-yr-olds was adopted because of the economic advantage of gaining an additional calf

Table 1. Least square means and SE for age, BW, and ADG during development

	Starting age, d	Starting BW, kg	Period 1 ADG, kg/d	Period 2 ADG, kg/d	Final BW, kg	Pubertal before breeding, %
Treatment						
Control	256 ± 1	263 ± 2	0.78 ± 0.02^{a}	0.70 ± 0.03^{a}	375 ± 3^{a}	89.6 ± 2.1
Stair-step	255 ± 1	262 ± 2	0.33 ± 0.02^{b}	0.93 ± 0.03^{b}	351 ± 3^{b}	93.9 ± 1.7
Breed type						
Angus	261 ± 1	276 ± 3^{a}	0.57 ± 0.03	0.81 ± 0.05	378 ± 5	81.7 ± 4.1^{a}
MARC I	256 ± 1	258 ± 3^{b}	0.55 ± 0.03	0.79 ± 0.05	358 ± 6	92.5 ± 2.5^{b}
MARC II	250 ± 1	251 ± 3^{b}	0.58 ± 0.03	0.82 ± 0.05	352 ± 5	93.5 ± 2.2^{b}
MARC III	255 ± 1	265 ± 3^{a,b}	0.51 ± 0.03	0.84 ± 0.05	363 ± 6	94.2 ±2.0^{b}
P-values						
Treatment (T)	0.74	0.58	<0.001	<0.001	<0.001	0.24
Breed type (B)	0.08	0.03	0.38	0.93	0.11	0.03
Year	0.16	0.02	0.45	<0.001	0.02	–
T × B	0.57	0.80	0.89	0.85	0.87	0.96

Means within columns with different superscripts differ ($P < 0.05$).

Table 2. Least squares means and SE for weaning performance

Cow age	Proportion of original cows weaning a calf			Weaning weight, kg		
	Control	Stair-step	Overall	Control	Stair-step	Overall
2-yr-old	0.81 ± 0.02	0.80 ± 0.02	0.80 ± 0.02	162 ± 1	166 ± 1	164 ± 1
3-yr-old	0.71 ± 0.03	0.73 ± 0.03	0.72 ± 0.02	186 ± 1	187 ± 1	186 ± 1
4-yr-old	0.65 ± 0.03	0.65 ± 0.03	0.65 ± 0.02	196 ± 2	198 ± 1	197 ± 1
5-yr-old	0.56 ± 0.03	0.62 ± 0.02	0.59 ± 0.02	201 ± 2	204 ± 2	203 ± 1
6-yr-old	0.51 ± 0.03	0.57 ± 0.02	0.54 ± 0.02	199 ± 2	205 ± 2	202 ± 1
7-yr-old	0.44 ± 0.03	0.49 ± 0.03	0.46 ± 0.02	200 ± 2	191 ± 2	200 ± 1
Effects		*P*-value			*P*-value	
Treatment (T)		0.28			0.007	
Breed (B)		0.42			0.014	
Cow age		<0.001			<0.001	
Calf sex		–			<0.001	
Calf age		–			<0.001	
T × B		0.93			0.99	
T × age		0.39			0.09	
B × age		0.79			<0.001	

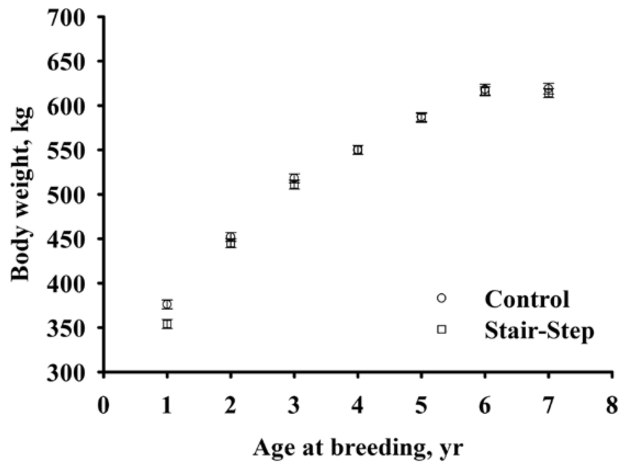

Figure 1. Breeding weight as cows age: treatment (T), $P = 0.06$; breed type (B), $P = 0.03$; age (A), $P < 0.001$; T × B, $P = 0.81$; T × A, $P = 0.05$; B × A, $P < 0.001$.

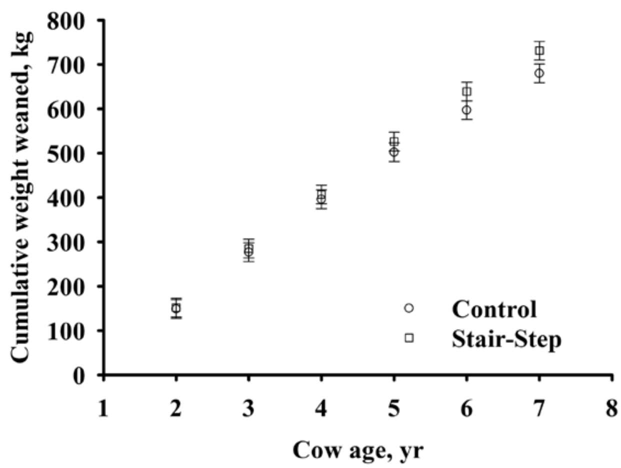

Figure 2. Cumulative weaning weight weaned: treatment (T), $P = 0.25$; breed type (B), $P = 0.59$; age (A), $P < 0.001$; T × B, $P = 0.98$; T × A, $P = 0.51$; B × A, $P = 0.98$.

over the lifetime of the cow (Núñez-Dominguez et al., 1991). Inadequate nutrition can result in a delay of or failure to reach puberty (Jourbert, 1954; Wiltbank et al., 1969; Ferrell, 1982). The practice of calving heifers as 2-yr-olds led to aggressive feeding practices to ensure heifers reached puberty and were of an adequate size to successfully calve at 2 yr of age. This aggressive feeding often resulted in heifers that were obese. While aggressive feeding helps ensure heifers reach sexual maturity in time to breed as yearlings, there is a potential for a decrease in productivity of over-fed heifers. Numerous studies in beef cattle have demonstrated that rapid weight gain during the peri-pubertal period has a permanent negative impact on milk production (Ferrell, 1982; Johnsson and Obst, 1984; Park et al., 1998). Pinney et al. (1972) found that lifetime productivity of obese heifers was lower than nonobese heifers. There has been considerable genetic selection to decrease the age of puberty (Morris et al., 2000). The need to reach ≥60% of the mature weight before breeding may have declined, offering the opportunity of alternative nutrient management models that avoid obesity in cattle selected for early puberty (Lardner et al., 2014).

Two general approaches have been studied in beef cattle. The first is to grow heifers to a smaller proportion of their mature weight at breeding (Freetly and Cundiff, 1997, 1998; Freetly et al., 2001; Roberts et al., 2009). Several studies have suggested that heifers can successfully be developed to approximately 55% of their mature BW (Funston and Deutscher, 2004; Lardner et al., 2014). In these studies, lighter weight heifers did not differ from their heavier counterparts in pregnancy rates. The second is limited growth during the peri-pubertal period followed by utilizing compensatory gain to allow heifers to reach a target BW at breeding (Clanton et al., 1983; Lynch et al., 1997; Grings et al., 1999, Freetly et al., 2001). Several studies have determined that there is minimal effect on first parity pregnancy rates when growth rates are slowed after weaning followed by a rapid increase in BW gain before breeding (Clanton et al., 1983; Lynch et al., 1997; Grings et al., 1999; Freetly et al., 2001). Freetly et al. (2014) found that heifers that had undergone the stair-step protocol had more primordial follicles than heifers on a constant weight gain, suggesting they may have a longer stayability in the herd. Some heifer development studies followed cows through their third parity (Funston and Deutsher, 2004; Lardner et al., 2014) while others evaluated cows only through their first parity. Less information is available on longer-term effects on lifetime productivity.

The control treatments in the current study would be considered a moderate rate of development. At the end of the developmental period, control heifers had reached 61% of their 7-yr-old BW, and stair-step heifers had reached 58% of their 7-yr-old BW. In the current study, stair-step heifers were lighter at breeding than heifers, but the treatment difference was not observed at older ages suggesting that modifying the growth pattern did not affect mature cow weights. In the current study, breed types ranged from 57% to 61% of their 7-yr-old BW at breeding as heifers. The Angus had reached the least at 57% and also had the least pubertal at breeding. Breed types did not differ in the proportion of cows weaning a calf suggesting that reaching a proportion of mature BW in the upper

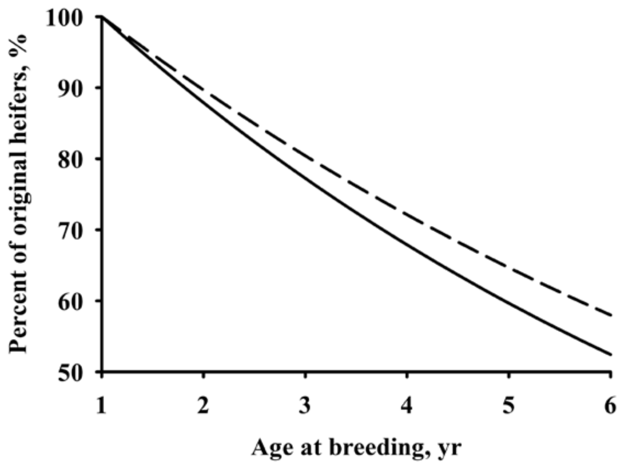

Figure 3. Decay curves for the percent of original heifers present at each breeding. The probability ($P < 0.01$) is that treatment specific curves fit the data better than a pooled curve. Percent of cows present was a function of breeding age in years, $f(\text{breeding age}) = 100e^{(k(\text{breeding age} - 1))}$. Control (—) $k = -0.1291 \pm 0.0062$ and stair-step (—) -0.1090 ± 0.0033.

50th percentile is adequate across a diverse group of *B. taurus* breed types.

In our earlier studies (Freetly et al., 2014; Amundson et al., 2015), we found a greater number of ovarian follicles in stair-step heifers at their first breeding leading us to hypothesize that they would have a delayed depletion of follicles resulting in increased stay-ability in the herd. Analyses of the rate of decay of cows present at breeding support this hypothesis; however, this advantage for cows raised on the stair-step protocol did not translate into more cows weaning a calf at each of the cow ages.

The role of peri-pubertal nutrition on subsequent milk production has been well documented. Both growth restriction and accelerated growth during this period have been associated with lower milk yields as cows (Ferrell, 1982; Johnsson and Obst, 1984; Buskirk et al., 1995). These changes in milk production have been shown to be persistent. Johnsson and Obst (1984) demonstrated that milk production continued to be reduced through 3 lactations when heifers were rapidly developed. In the current study, stair-step heifers weaned heavier calves than controls. A potential mechanism for this increase may have been an increase in milk production; however, Grings et al. (1999) found no differences in milk yield between control and stair-step heifers when measured by weigh-suckle-weigh. Weaning weights differed between breed types and cow age. In general, breed-types with the greater 6- and 7-yr-old breeding BW also were greater at weaning.

Cumulative weight weaned is a function of the number of calves weaned and weaning weight of those calves. Calves from stair-step heifers had greater weaning weights, but they did not wean more cumulative BW across the first six parturitions. Rates of decrease in cows present at breeding suggest that more stair-step cows are present at the sixth breeding. This observation is numerically consistent with the proportion of cows weaning a calf as a 7-yr-old; however, the lack of a treatment difference in the cows weaning a 6th calf contributed to no treatment difference in cumulative calf weight weaned.

Advantages of a stair-step heifer development program are increase options in nutrient management during development and a potential increase in cow retention, but in the current study, there were limited advantages in calf production. In the current study, stair-step heifers were 58% of their 7-yr-old weight compared to the controls at 61% at breeding. The control heifers in this study would not be considered to be obese. Developing Controls to a greater proportion of their mature weight may have increased treatment differences.

CONCLUSION

A diverse genetic population of cattle within *B. taurus* was tested and responses in calf production did not differ between stair-step growth pattern and a more constant nonobese growth pattern.

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Conflict of interest statement. The authors have no conflict of interest to declare.

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