1-1-2011

CASE STUDY: The effects of maternal nutrition on steer progeny performance

A. F. Summers
University of Nebraska, West Central Research and Extension Center

K. H. Ramsay
Rex Ranch

Richard N. Funston
University of Nebraska - Lincoln, rfunston2@unl.edu

The Professional Animal Scientist 27 (2011):251–256

CASE STUDY: The effects of maternal nutrition on steer progeny performance

A. F. Summers,* K. H. Ramsay,† and R. N. Funston*[1]
*University of Nebraska, West Central Research and Extension Center, North Platte 69101; and
†Rex Ranch, Ashby, NE 69333

ABSTRACT

Two locations on a commercial ranch in the Nebraska Sandhills were used to determine the effects of maternal nutrition on male progeny. Crossbred, spring-calving, multiparous cows were managed in a year-round grazing system. Cows at one location (yr 1 = 754; yr 2 = 700) received the equivalent of 0.95 kg/d (DM; 31.6% CP; HN) of supplement, and cows at the second location (yr 1 = 673; yr 2 = 766) received 0.37 kg/d (DM; LN) of the same supplement delivered 3 times weekly while grazing winter range from December through February. After weaning, a random group (yr 1 = 50 HN, 50 LN; yr 2 = 50 HN, 50 LN) of male progeny entered the feedlot and were slaughtered 218 d later. There was a significant ($P \leq 0.03$) year × treatment interaction, with yr-1 HN steers having the greatest reimplant BW, final BW, DMI, G:F ratios, and HCW. Year-2 HN steers had greater ($P = 0.03$) proportions grading USDA Choice or greater compared with yr-1 HN and LN steers. Marbling scores were greater for HN steers compared with LN steers ($P = 0.05$) and steers from yr 2 compared with yr 1 ($P < 0.01$). Year-2 steers had greater ($P < 0.01$) proportions grading USDA Choice compared with yr-1 steers. Increased maternal nutrition resulted in increased steer performance and carcass characteristics in yr 1 and greater marbling scores in HN steers compared with LN steers.

Key words: beef cattle, carcass quality, maternal nutrition

INTRODUCTION

Minimizing costs while maximizing profitability is a major goal in beef cattle production. Utilizing dormant forages throughout the winter reduces production costs by increasing grazing season length and decreasing the amount of harvested forage needed in beef cattle production systems (Adams et al., 1994); however, nutrient content of dormant forage is low and does not meet the energy demands of cows during the last trimester of gestation (NRC, 2000). Not meeting energy requirements of the dam not only influences dam productivity, but the performance of subsequent offspring as well (Houghton et al., 1990; Dunn and Moss, 1992; Beaty et al., 1994; Wu et al., 2004; Hess et al., 2005; Underwood et al., 2010). Providing protein supplementation through winter grazing has been a common practice to maintain cow BCS (Banta et al., 2006; Stalker et al., 2006; Martin et al., 2007; Larson et al., 2009). Providing protein supplementation has increased progeny weaning BW (Stalker et al., 2006; Martin et al., 2007), improved postweaning calf health (Mulliniks et al., 2008; Larson et al., 2009), and increased HCW and the proportion of calves achieving USDA quality grades of Choice or greater (Larson et al., 2009). These results indicate maternal nutrition during gestation can influence postnatal growth and health, hypothesized as fetal programming (Barker et al., 1993). The objective of the current study was to evaluate the effects of 2 protein supplementation levels for dams grazing dormant Sandhills forage on subsequent steer progeny growth, feed efficiency, and carcass traits.

MATERIALS AND METHODS

Cow and Calf Management

The University of Nebraska–Lincoln Institutional Animal Care and Use Committee approved the procedures and facilities used in this experiment. A 2-yr study was conducted at 2 units of the Rex Ranch, Ashby, Nebraska. Pregnant, multiparous, composite beef cows of similar genetics (50% Red Angus, 25% Simmental, and 25% South Devon or other breeds) were managed in a year-round grazing system. Cows were pasture exposed to bulls of simi-

[1] Corresponding author: rfunston2@unl.edu

Table 1. Composition of backgrounding and finishing diets fed to steer progeny of HN and LN cows[1]

	DM, %	
Item	Backgrounding[2]	Finishing[3]
Dry-rolled corn	15	48
Wet corn gluten feed	40	40
Grass hay	35	7
Supplement[4]	10	5

[1]HN = dams supplemented with 1.06 and 0.83 kg/d of 31.6% CP cube (DM basis) during late gestation and 5.63 and 4.86 kg/d of meadow hay during calving for yr 1 and 2, respectively; LN = dams supplemented with 0.35 and 0.38 kg/d of protein supplement during late gestation and 4.14 and 5.83 kg/d of meadow hay during calving for yr 1 and 2, respectively.

[2]Contained 16% CP, 1.1% Ca, 0.58% P, and 1.2% K (DM basis).

[3]Contained 14% CP, 0.67% Ca, 0.56% P, and 0.9% K (DM basis).

[4]Provided dietary concentration of 28 g/t of monensin and 10 g/t of tylosin (DM basis, Elanco Animal Health, Indianapolis, IN).

lar breeding at each location for 70 d beginning mid-June through August. Forty-five days after the breeding season, pregnancy rates were determined via rectal palpation.

Cows grazed dormant forage pastures of similar quality (Patterson et al., 2003) from November to late February with a protein supplement (31.6% CP cubes) delivered 3 times weekly. The supplement offered was similar to that reported by Larson et al. (2009) and contained 62.0% dried distillers grains plus solubles, 11.0% wheat middlings, 9.0% cottonseed meal, 5.0% dried corn gluten feed, 5.0% molasses, 2.0% urea, and 6.0% vitamin and trace mineral premix on a DM basis. The supplement was formulated to meet vitamin and trace mineral requirements of the 3-yr-old cows and supply 80 mg of monensin per day per animal (Rumensin, Elanco Animal Health, Indianapolis, IN). The supplement provided was approximately 47.6% RUP and 89.4% TDN on a DM basis (Larson et al., 2009).

Supplement and meadow hay were offered to cows at both locations at the discretion of the manager, with cows at one location (yr 1 = 754; yr 2 = 700) receiving higher levels of supplement (**HN**; 1.06 kg/d yr 1; 0.83 kg/d yr 2, DM basis) and cows at the second location (yr 1 = 673; yr 2 = 766) being fed lower levels of supplement (**LN**; 0.35 kg/d yr 1; 0.38 kg/d yr 2, DM basis). During calving (March and April), cows received meadow hay in the form of large round bales, with HN cows receiving 5.63 kg/d (DM) in yr 1 and 4.86 kg/d (DM) in yr 2 and LN cows receiving 4.14 and 5.83 kg/d (DM) in yr 1 and yr 2, respectively. Differing levels of supplementation and hay fed resulted from managers at each of the 2 units feeding the cows at their discretion. After weaning (early to mid-September), calves grazed meadow pasture while receiving 1.21 kg/d (DM) of the CP supplement until shipping in mid-November.

Steer Calf Management

Each year a random sample of steers from each treatment group (50 HN, 50 LN) was shipped approximately 212 km to the University of Nebraska West Central Research and Extension Center, North Platte, Nebraska. All steers were fed together in one pen and limit fed a starter diet (Table 1) for 5 d after arrival; steers were then weighed on 2 consecutive days to calculate initial BW. On the second day an implant was administered providing 20 mg of estradiol benzoate and 200 mg of progesterone (Synovex S, Fort Dodge Animal Health, Overland Park, KS). Steers were transitioned to a finishing diet (Table 1) over 21 d. Approximately 100 d before slaughter, steers were implanted with 24 mg of estradiol and 120 mg of trenbolone acetate (Revalor S, Intervet, Millsboro, DE). Steers were slaughtered at a commercial abattoir 218 d after entering the feedlot. Final BW was calculated from HCW divided by a common dressing percentage (63%), and carcass data were collected after a 24-h chill.

Steer DMI was calculated using the DMI prediction equation established by Tedeschi et al. (2006), where DMI = 4.18 + (1.98 × ADG) + (0.0013 × $MBW^{0.75}$) + (0.019 × EBF), where $MBW^{0.75}$ represents the mean metabolic BW and EBF represents empty body fat percentage. Empty body fat percentage was calculated using the equation developed by Guiroy et al. (2001), where EBF = 17.76107 + (4.68142 × FT) + (0.01945 × HCW) + (0.81855 × QG) − (0.06754 × LMA), where FT represents 12th-rib fat thickness and LMA represents LM area.

Economic Evaluation

To determine the effect of the 2 supplementation levels on profitability, a partial budget analysis was conducted. Supplementation costs were valued at actual purchase price plus a delivery charge ($0.07/kg). Meadow hay values were taken from Nebraska state average monthly price based on the USDA Agricultural Marketing Service (USDA-AMS, 2007a, 2008a). Calf sale prices were Nebraska weighted average feeder cattle price reported for the given year at the time of entry into the feedlot as reported by the USDA Agricultural Marketing Service (USDA-AMS, 2007b, 2008b). Feedlot ration was valued at $0.14/kg. Veterinary charges, trucking, yardage, and implants were charged as nonfeed costs at $0.50/d. The value of steers at slaughter was based on Nebraska dressed steer price for the day of slaughter (USDA-AMS, 2008c, 2009a), with grid premiums and discounts applied as reported by the USDA Agricultural Marketing Service (USDA-AMS, 2008d, 2009b).

Statistical Analysis

Supplementation levels were applied to the dams on a location level (n = 1) repeated over a 2-yr period; therefore, location was considered the experimental unit for steer performance and carcass data. Data were analyzed using PROC MIXED (SAS Inst. Inc., Cary, NC), with $P \leq 0.05$ considered significant. The statistical model included dam treatment, year, and dam treatment × year. Proportions of steers grading USDA Choice and USDA QG of modest or higher were analyzed using χ^2 procedures in PROC FREQ of SAS.

RESULTS AND DISCUSSION

Performance and Carcass Quality

Steer feedlot performance data are presented in Table 2. Initial BW did not differ ($P = 0.17$) between HN and LN steers; however, steers in yr 1 were 23 kg heavier ($P < 0.01$) than steers from the same treatments in yr 2. These data for initial BW disagree with previous studies in which calves from supplemented or increased supplemented dams had greater weaning weights and feedlot initial BW (Beaty et al., 1994; Spitzer et al., 1995; Stalker et al., 2006; Larson et al., 2009). Calves entering the feedlot from those studies were placed in the feedlot 14 d postweaning, whereas calves in this study were not shipped to the feedlot until approximately 8 wk after weaning and were allowed to graze subirrigated meadows and received 1.21 kg/d of 31.6% CP supplement. In the studies conducted by Stalker et al. (2006) and Larson et al. (2009), pregnant cows were offered the equivalent of 0.45 kg/d supplement or no supplement. In the present study, cows were provided supplement at both locations, with HN cows receiving approximately 2.5 times more supplement than LN cows, and LN cows receiving supplement levels similar to Stalker et al. (2006) and Larson et al. (2009). Reimplant BW ($P = 0.03$) and final BW ($P = 0.01$) were greatest for yr-1 HN steers. Average daily gain, DMI, and efficiency calculated as G:F were greatest ($P < 0.01$) for yr-1 HN steers.

Steer carcass data are summarized in Table 3. Hot carcass weight was greater ($P = 0.01$) for yr-1 HN steers compared with steers from all other groups. The proportion of steers grading USDA Choice was 32 and 33% greater ($P < 0.01$) for HN and LN steers from yr 2 compared with yr 1. Furthermore, yr-2 HN steers had a greater ($P = 0.03$) proportion grading USDA modest or greater compared with yr-1 HN and LN steers.

Steers from HN cows had greater marbling scores compared with steers from LN cows (434 vs. 415, ±7, $P \leq 0.05$), and yr-2 steers had greater ($P < 0.01$) marbling scores compared with yr-1 steers. In a review on fetal skeletal muscle development, Du et al. (2010) reported the importance of maternal nutrition on muscle development and the ability to increase intramuscular fat deposits through recruitment of mesenchymal stem cells to adipogenesis rather than myogenesis, which later lead to marbling. It is hypothesized greater marbling scores reported in HN steers compared with LN steers results from fetal programming.

There were no differences ($P \geq 0.26$) in 12th-rib fat, LM area, or YG when comparing steers from HN cows to those from LN cows; however, differences were significant ($P < 0.08$) between yr 1 and yr 2. No differences

Table 2. Effects of late-gestation maternal protein supplementation level on progeny steer feedlot performance

	Treatment[1]					Treatment P-value[2]		
	HN		LN					
Item	Yr 1	Yr 2	Yr 1	Yr 2	SEM	Trt	Yr	Trt × Yr
Initial BW, kg	239	216	236	213	2	0.17	<0.01	0.82
Reimplant BW, kg	459[a]	410[c]	443[b]	412[c]	4	0.09	<0.01	0.03
Final BW, kg	631[a]	570[c]	605[b]	574[c]	6	0.07	<0.01	0.01
ADG, kg/d	1.80[a]	1.62[b]	1.69[b]	1.66[b]	0.02	0.11	<0.01	<0.01
DMI,[3] kg/d	8.41[a]	8.05[b]	8.19[b]	8.13[b]	0.09	0.12	<0.01	<0.01
G:F, g/kg	213.67[a]	200.63[b]	206.12[b]	203.57[b]	1.27	0.15	<0.01	<0.01

[a–c]Means within a row with different superscripts differ ($P < 0.05$).

[1]HN = dams supplemented with 1.06 and 0.83 kg/d of 31.6% CP cube (DM basis) during late gestation and 5.63 and 4.86 kg/d of meadow hay during calving for yr 1 and 2, respectively; LN = dams supplemented with 0.35 and 0.38 kg/d of protein supplement during late gestation and 4.14 and 5.83 kg/d of meadow hay during calving for yr 1 and 2, respectively.

[2]Trt = dam treatment; Yr = year; Trt × Yr = dam treatment by year interactions.

[3]DMI calculated using the prediction formula presented by Tedeschi et al. (2006), where DMI = 4.18 + (1.98 × ADG) + (0.0013 × $MBW^{0.75}$) + (0.019 × EBF), where $MBW^{0.75}$ represents the mean metabolic BW and EBF represents empty body fat percentage.

Table 3. Effects of late-gestation maternal protein supplementation level on progeny steer carcass data

	Treatment[1]					Treatment *P*-value[2]		
	HN		LN					
Item	Yr 1	Yr 2	Yr 1	Yr 2	SEM	Trt	Yr	Trt × Yr
HCW, kg	397[a]	359[c]	381[b]	362[c]	4	0.07	<0.01	0.01
Marbling score[3]	410	458	388	441	10	0.05	<0.01	0.79
12th-rib fat, cm	1.22	1.17	1.26	1.13	0.05	0.93	0.08	0.44
Empty body fat, %	28.62	28.92	28.48	28.78	0.33	0.67	0.36	0.99
LM area, cm²	94.38	81.39	93.03	79.96	1.25	0.26	<0.01	0.96
YG	2.74	3.02	2.71	3.07	0.10	0.95	<0.01	0.64
QG, % Sm[4] or greater	46[b]	78[a]	48[b]	81[a]		0.78	<0.01	<0.01
QG, % Md[5] of greater	12[bc]	29[a]	4[c]	19[ab]		0.07	<0.01	0.03

[a–c]Means within a row with different superscripts differ ($P < 0.05$).

[1]HN = dams supplemented with 1.06 and 0.83 kg/d of 31.6% CP cube (DM basis) during late gestation and 5.63 and 4.86 kg/d of meadow hay during calving for yr 1 and 2, respectively; LN = dams supplemented with 0.35 and 0.38 kg/d of protein supplement during late gestation and 4.14 and 5.83 kg/d of meadow hay during calving for yr 1 and 2, respectively.

[2]Trt = dam treatment; Yr = year; Trt × Yr = dam treatment by year interactions.

[3]Where 400 = small[0].

[4]Sm = small quality grade, USDA low Choice.

[5]Md = modest quality grade, USDA average Choice.

($P \geq 0.23$) occurred between groups for empty body fat percentage.

Treatments in yr 1 differed slightly from yr 2 in amount of supplement provided; however, in both years, HN cows received greater levels of late-gestation supplementation. Hay offered at calving did differ between yr 1 and yr 2, with HN cows from yr 1 receiving 1.49 kg/d more hay than LN cows and in yr 2 LN cows receiving 0.97 kg/d more hay than HN cows. Differing levels of supplementation and hay fed resulted from managers at each of the 2 units feeding cows at their discretion. Nutrient availability both pre- and postpartum can influence milk production (Wiltbank et al., 1962; Totusek et al., 1973; Lalman et al., 2000), which may explain why there was no difference between treatments in yr 2. Johnson et al. (2003) reported an increase in milk production during early lactation of 1 kg of milk per 0.33 kg of forage DMI in Brangus cows. Although slightly different body maintenance requirements between Brangus and Angus cows are used by the NRC (2000) to calculate cow requirements, similar values are used for peak milk yield. Using values reported by Johnson et al. (2003), LN cows would be predicted to produce approximately 3 kg more milk compared with HN cows during early lactation of yr 2; however, milk production was not measured. The role of neonatal environment and its ability to influence postnatal programming have been reported (Francis et al., 1999; Drake and Walker, 2004). Increased nutrient availability at calving for LN cows, increasing early milk production, compared with HN cows could have influenced calf postnatal development, resulting in no significant differences between treatments in yr 2.

Economic Evaluation

Data for the economic evaluation are summarized in Table 4. Data represent actual values for the years of the study (2007 to 2009). In yr 1, if calves were sold in November, HN calves were valued at \$9.19/calf greater than calves from LN cows; however, net returns for HN calves were \$8.84/calf less than those for LN calves because of increased amounts of supplement and hay offered to HN cows. Year-2 calves also had greater sale values for HN calves. Unlike yr 1, HN calf value was \$9.05/calf greater than that of LN calves because of increased hay amounts offered to LN cows during yr 2. Carcass value was greater for yr-1 steers compared with yr-2 steers from both treatments. In yr 1, net profit difference through the feedlot phase was \$40.63/steer greater for steers born to HN cows compared with those born to LN cows; however, in yr 2 net profit difference was \$16.88/steer greater for LN steers compared with HN steers. Differences between returns are related to HCW. In yr 1 HCW was significantly greater ($P < 0.01$) for HN steers compared with LN calves, whereas in yr 2 difference in returns was due to a numerical, statistically nonsignificant, difference in HCW ($P = 0.95$). Fed cattle base prices were \$0.09/kg higher in yr 1 compared with yr 2, which along with the heavier HCW from yr 1 added to the differences in carcass values between the 2 yr.

Table 4. Partial budget analysis of maternal protein supplementation during late gestation to weaning and weaning to slaughter

	Treatment[1]			
	HN		LN	
Item	Yr 1	Yr 2	Yr 1	Yr 2
Cow-calf phase				
Costs, $/cow				
Protein supplement	6.60	5.17	2.18	2.37
Meadow hay	51.15	45.52	37.54	54.53
Returns, $/calf				
Calf sale price[2]	626.28	469.95	617.09	467.11
Net profit difference	568.53	419.26	577.37	410.21
Feedlot phase				
Costs, $/steer				
Purchase cost[3]	661.70	509.41	654.09	500.38
Feedlot feed cost[4]	365.67	354.69	358.96	357.13
Returns, $/steer				
Carcass value	1,302.63	1,030.54	1,247.68	1,040.83
Net profit difference	275.26	166.44	234.63	183.32

[1]HN = dams supplemented with 1.06 and 0.83 kg/d of 31.6% CP cube (DM basis) during late gestation and 5.63 and 4.86 kg/d of meadow hay during calving for yr 1 and 2, respectively; LN = dams supplemented with 0.35 and 0.38 kg/d of protein supplement during late gestation and 4.14 and 5.83 kg/d of meadow hay during calving for yr 1 and 2, respectively.

[2]Value of steer calves after grazing meadow hay and receiving 1.21 kg/d of 31.6% CP cube (DM basis) for approximately 8 wk.

[3]Value of steer calves.

[4]Value based on $0.14/kg feed cost for 218 d and including yardage at $0.50/d.

IMPLICATIONS

Providing increased late-gestation supplementation to the dam did not affect steer initial BW at feedlot entry; however, steers from HN cows in yr 1 had greater final BW and HCW than did steers from LN cows. Average marbling scores were greater for HN calves compared with LN calves, suggesting a fetal programming effect with increased dam supplementation altering fetal development. Based on these preliminary findings, additional research in a more controlled research environment is warranted to further elucidate effects of maternal nutrition on subsequent steer progeny.

LITERATURE CITED

Adams, D. C., R. T. Clark, S. A. Coady, J. B. Lamb, and M. K. Nielsen. 1994. Extended grazing systems for improving economic returns from Nebraska Sandhills cow/calf operations. J. Range Manage. 47:258.

Banta, J. P., D. L. Lalman, F. N. Owens, C. R. Krehbiel, and R. P. Wettemann. 2006. Effects of interval-feeding whole sunflower seeds during mid to late gestation on performance of beef cows and their progeny. J. Anim. Sci. 84:2410.

Barker, D. J. P., C. N. Martyn, C. Osmond, C. N. Hales, and C. H. D. Fall. 1993. Growth in utero and serum cholesterol concentrations in adult life. BMJ 307:1524.

Beaty, J. L., R. C. Cochran, B. A. Lintzenich, E. S. Vanzant, J. L. Morrill, R. T. Brandt, and D. E. Johnson. 1994. Effect of frequency of supplementation and protein concentration in supplements on performance and digestion characteristics of beef cattle consuming low-quality forages. J. Anim. Sci. 72:2475.

Drake, A. J., and B. R. Walker. 2004. The intergenerational effects of fetal programming: Non-genomic mechanisms for the inheritance of low birth weight and cardiovascular risk. J. Endocrinol. 180:1.

Du, M, J. Tong, J. Zhao, K. R. Underwood, M. Zhu, S. P. Ford, and P. W. Nathanielsz. 2010. Fetal programming of skeletal muscle development in ruminant animals. J. Anim. Sci. 88(E. Suppl.):E51–E60.

Dunn, T. G., and E. G. Moss. 1992. Effects of nutrient deficiencies and excesses on reproductive efficiency of livestock. J. Anim. Sci. 70:1580.

Francis, D., J. Diorio, D. Liu, and M. J. Meaney. 1999. Nongenomic transmission across generations of maternal behavior and stress responses in the rat. Science 286:1155.

Guiroy, P. J., D. G. Fox, L. O. Tedeschi, M. J. Baker, and M. D. Cravey. 2001. Predicting individual feed requirements of cattle fed in groups. J. Anim. Sci. 79:1983.

Hess, B. W., S. L. Lake, E. J. Scholljegerdes, T. R. Weston, V. Nayigihugu, J. D. C. Molle, and G. E. Moss. 2005. Nutritional controls of beef cow reproduction. J. Anim. Sci. 83(E. Suppl.):E90–E106.

Houghton, P. L., R. P. Lemenager, L. A. Horstman, K. S. Hendrix, and G. E. Moss. 1990. Effects of body composition, pre- and postpartum energy level and early weaning on reproductive performance of beef cows and preweaning calf gains. J. Anim. Sci. 68:1438.

Johnson, C. R., D. L. Lalman, M. A. Brown, L. A. Appeddu, D. S. Buchanan, and R. P. Wettemann. 2003. Influence of milk production potential on forage dry matter intake by multiparous and primiparous Brangus females. J. Anim. Sci. 81:1837.

Lalman, D. L., J. E. Williams, B. W. Hess, M. G. Thomas, and D. H. Keisler. 2000. Effect of dietary energy on milk production and metabolic hormones in thin, primiparous beef heifers. J. Anim. Sci. 78:530.

Larson, D. M., J. L. Martin, D. C. Adams, and R. N. Funston. 2009. Winter grazing system and supplementation during late gestation influence performance of beef cows and steer progeny. J. Anim. Sci. 87:1147.

Martin, J. L., K. A. Vonnahme, D. C. Adams, G. P. Lardy, and R. N. Funston. 2007. Effects of dam nutrition on growth and reproductive performance of heifer calves. J. Anim. Sci. 85:841.

Mulliniks, J. T., S. H. Cox, S. L. Ivey, C. P. Mathis, J. E. Sawyer, and M. K. Petersen. 2008. Cow nutrition impacts feedlot pull rate. Proc. West. Sec. Am. Soc. Anim. Sci. 59:91.

NRC. 2000. Nutrient Requirements of Beef Cattle. 7th ed. Natl. Acad. Press, Washington, DC.

Patterson, H. H., D. C. Adams, T. J. Klopfenstein, R. T. Clark, and B. Teichert. 2003. Supplementation to meet metabolizable protein requirements of primiparous beef heifers: II. Pregnancy and economics. J. Anim. Sci. 81:563.

Spitzer, J. C., D. G. Morrison, R. P. Wettemann, and L. C. Faulkner. 1995. Reproductive responses and calf birth and weaning weights as affected by body condition at parturition and postpartum weight gain in primiparous beef cows. J. Anim. Sci. 73:1251.

Stalker, L. A., D. C. Adams, T. J. Klopfenstein, D. M. Feuz, and R. N. Funston. 2006. Effects of pre- and postpartum nutrition on reproduction in spring calving cows and calf feedlot performance. J. Anim. Sci. 84:2582.

Tedeschi, L. O., D. G. Fox, M. J. Baker, and D. P. Kirschten. 2006. Identifying differences in feed efficiency among group-fed cattle. J. Anim. Sci. 84:767.

Totusek, R., D. W. Arnett, G. L. Holland, and J. V. Whiteman. 1973. Relation of estimation method, sampling interval and milk composition to milk yield of beef cows and calf gain. J. Anim. Sci. 37:153.

Underwood, K. R., J. F. Tong, P. L. Price, A. J. Roberts, E. E. Grings, B. W. Hess, W. J. Means, and M. Du. 2010. Nutrition during mid to late gestation affects growth, adipose tissue deposition and tenderness in cross-bred beef steers. Meat Sci. 86:588.

USDA-AMS. 2007a. Nebraska-Iowa weekly hay reports. Accessed March 1, 2010. http://search.ams.usda.gov/mndms/2007/03/wh_gr31020070315.txt.

USDA-AMS. 2007b. Nebraska weekly feeder cattle auction summary. Accessed March 1, 2010. http://search.ams.usda.gov/mndms/2007/11/WH_LS79520071119.txt.

USDA-AMS. 2008a. Nebraska-Iowa weekly hay reports. Accessed March 1, 2010. http://search.ams.usda.gov/mndms/2008/03/WH_GR31020080320.txt.

USDA-AMS. 2008b. Nebraska weekly feeder cattle auction summary. Accessed March 1, 2010. http://search.ams.usda.gov/mndms/2008/11/WH_LS79520081124.txt.

USDA-AMS. 2008c. 5 area weekly weighted average direct slaughter cattle. Accessed March 1, 2010. http://www.ams.usda.gov/mnreports/lm_ct150.txt.

USDA-AMS. 2008d. National weekly direct slaughter cattle–premiums and discounts. Accessed March 1, 2010. http://www.ams.usda.gov/mnreports/lm_ct155.txt.

USDA-AMS. 2009a. 5 area weekly weighted average direct slaughter cattle. Accessed March 1, 2010. http://www.ams.usda.gov/mnreports/lm_ct150.txt.

USDA-AMS. 2009b. National weekly direct slaughter cattle–premiums and discounts. Accessed March 1, 2010. http://www.ams.usda.gov/mnreports/lm_ct155.txt.

Wiltbank, J. N., W. W. Rowden, J. E. Ingalls, K. E. Gregory, and R. M. Koch. 1962. Effects of energy level on reproductive phenomena of mature Hereford cows. J. Anim. Sci. 21:219.

Wu, G., F. W. Bazer, T. A. Cudd, C. J. Meininger, and T. E. Spencer. 2004. Maternal nutrition and fetal development. J. Nutr. 134:2169.