

Impact of supplemental protein source offered to primiparous heifers during gestation on II. Progeny performance and carcass characteristics

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ABSTRACT: A 3-yr study using primiparous cross-bred beef heifers ($n = 114$) was conducted to determine the effects of protein supplement during late gestation on progeny performance and carcass characteristics. Pregnant heifers were stratified by heifer development system, initial BW, and AI service sire and placed in an individual feeding system. Heifers were offered meadow hay (8 to 11% CP) from early November to mid-February and provided no supplement (CON; $n = 37$), 0.83 kg/d (DM basis) of a dried distillers grains with solubles–based supplement (HI; $n = 39$), or 0.83 kg/d (DM basis) of a dried corn gluten feed–based supplement (LO; $n = 38$). Supplements were designed to be isonitrogenous (28% CP) and isocaloric but to differ in RUP with HI (59% RUP) having greater levels of RUP than LO (34% RUP). After the individual feeding period, heifers were placed in a drylot for calving. All heifers were bred using a fixed-timed AI protocol and pairs were moved to a commercial ranch in the Nebraska Sandhills for summer grazing. Calf weaning BW did not differ ($P = 0.14$) based on maternal diet. However, feedlot entry BW was greater ($P = 0.03$) for HI compared with CON calves. Average daily gain during the initial feedlot phase tended ($P = 0.10$) to be

greatest for calves born to CON dams and lowest for calves born to LO dams. However, overall ADG was similar ($P = 0.50$) for the entire feedlot period. Residual feed intake during the reimplant and total feeding period was improved in calves born to supplemented dams in yr 2 and 3 compared with calves born to CON dams. There was no difference in final BW among treatments ($P = 0.71$). Hot carcass weight was similar ($P = 0.72$) among treatments; however, steers had greater ($P < 0.01$) HCW than heifers. Furthermore, percent empty body fat and 12th rib fat thickness were lowest ($P = 0.05$ and $P = 0.04$) for calves born to LO dams. Tenderness measured by Warner-Bratzler shear force was increased ($P = 0.03$) in longissimus samples from calves from CON dams compared to calves from LO dams. Similarly, crude fat levels tended to be greater ($P = 0.07$) for calves from CON dams compared with calves from LO dams. Based on these data, providing RUP supplements, similar to those used in this study, to primiparous heifers in late gestation consuming ad libitum grass hay resulted in increased initial feedlot BW for HI compared to CON calves, improved feed efficiency, and altered carcass characteristics in calves born to supplemented compared with CON dams.

Key words: beef cattle, maternal nutrition, protein supplementation

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INTRODUCTION

Previous research reports late gestation protein supplementation influences multiparous cow progeny performance, carcass quality, and health (Stalker et al., 2006, 2007; Martin et al., 2008; Mulliniks et al., 2008; Larson et al., 2009). These results support the

fetal programming hypothesis, which suggests that maternal environment during gestation can influence progeny postnatal growth and health (Barker et al., 1993). Most studies concerning primiparous heifer prepartum nutrition focus on how nutritional treatments impact reproductive performance (Bellows et al., 1982, 2001; Wiley et al., 1991; Lammoglia et al., 1997; Patterson et al., 2003; Martin et al., 2005; Engel et al., 2008; Sullivan et al., 2009). However, a limited number of studies report the impact primiparous heifer nutrition during late gestation may have

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on subsequent progeny performance through weaning (Corah et al., 1975; Martin et al., 2005; Engel et al., 2008)

Corah et al. (1975) reported altered birth and weaning BW for calves born to heifers receiving 65% of their energy requirement during late gestation. Pregnant heifers have added nutrient requirements during late gestation compared with mature cows due to their own growth requirement as well as the growing fetus and maintenance requirements (Caton et al., 2007). Not meeting energy requirements of the dam can impact not only her productivity but the performance of subsequent offspring (Houghton et al., 1990; Dunn and Moss, 1992; Beaty et al., 1994; Wu et al., 2004; Hess et al., 2005; Underwood et al., 2010). The objective of the current study was to evaluate the effects of RUP supplementation levels on primiparous heifer progeny growth, feed efficiency, and carcass quality.

MATERIALS AND METHODS

Primiparous Heifer Management

The University of Nebraska-Lincoln Institutional Animal Care and Use Committee approved the procedures and facilities used in this experiment.

Primiparous heifer management has been reported in detail (Summers et al., 2015). In short, each October, pregnant heifers (yr 1, $n = 38$; yr 2, $n = 40$; and yr 3, $n = 36$) were placed in a Calan Broadbent individual feeding system (American Calan; Northwood, NH) and acclimated to the individual feeding bunks for approximately 25 d before the beginning of the feeding trial. Following the acclimation period, heifers ($n = 114$) were offered meadow hay (8–11% CP, DM basis) from early November to mid February (yr 1 and 3 = 84 d and yr 2 = 80 d) and provided no supplement (CON; $n = 37$), 0.83 kg/d (DM basis) of a dried distillers grains with solubles (DDGS)-based supplement (HI; $n = 39$), or 0.83 kg/d (DM basis) of a dried corn gluten feed-based supplement (LO; $n = 38$). Supplements (Table 1) were designed to be isonitrogenous (28% CP, DM basis) and isocaloric but to differ in RUP with HI (59% RUP) having greater levels of RUP than LO (34% RUP).

After the individual feeding period, heifers were placed in a drylot through calving and remained in a single group through weaning. After AI, heifers and their calves were moved 43 km to a commercial ranch in the Nebraska Sandhills (Sutherland, NE) for summer grazing. Cow-calf pairs were returned to the West Central Research and Extension Center (WCREC;

Table 1. Composition of high and low RUP supplements offered to heifers during late gestation

Item	Percent DM	
	HI ¹	LO ²
DDGS ³	99.0	–
CGF ⁴	–	72.4
Corn germ	–	24.5
Urea	–	2.1
Trace minerals and vitamins	1.0	1.0
Nutrient analysis ⁵		
CP, %	28.2	28.0
RUP, % CP	59.0	34.0
TDN	78.9	78.8
Crude fat, %	11.9	11.9

¹HI = 0.83 kg/d (DM basis) of a dried distillers grains with solubles-based supplement.

²LO = 0.83 kg/d (DM basis) of a dried corn gluten feed-based supplement.

³DDGS = dried distillers grains with solubles.

⁴CGF = dried corn gluten feed.

⁵Wet chemistry; Ward Laboratories Inc., Kearney, NE; RUP based on the NRC (1996) estimated values.

North Platte, NE) in late October for final pregnancy diagnosis and weaning.

Prewaning Calf Management

At approximately 2 mo of age, all calves received an infectious bovine rhinotracheitis, parainfluenza-3 virus, bovine respiratory syncytial virus, and bovine viral diarrhea type I and II vaccine (BoviShield 5; Zoetis, Florham Park, NJ). At vaccination, calves were also weighed and branded and male calves were castrated. Calves were shipped with cows to summer grazing pastures and returned to the WCREC in late October for weaning. Upon arrival at the WCREC, calves were given an injection of BoviShield 5 (Zoetis) before weaning. At weaning, calves were weighed; electronic identification tags were applied (yr 2 and 3); calves were vaccinated against bovine rotavirus-coronavirus, clostridium perfringens type C and D, and *Escherichia coli* bacterin-toxoid (Guardian; Intervet, Millsboro, DE); and topical endectocide was applied (Ivermectin; Aspen Veterinary, Liberty, MO).

Calf Feedlot Management

After weaning, calves were limit fed a starter diet for 5 d at 2.0% BW before determining initial feedlot BW. Implants were administered providing 20 mg of estradiol benzoate and 200 mg progesterone (Synovex S; Zoetis) to steers and 20 mg of estradiol benzoate and 200 mg testosterone to heifers (Synovex H; Zoetis). Calves were transitioned (21 d) to a common

Table 2. Composition of backgrounding and finishing diets fed in the feedlot to progeny of primiparous heifers fed either no supplement or 0.83 kg/d high RUP or 0.83 kg/d low RUP supplement during the last trimester of gestation

Item	DM, %	
	Backgrounding	Finishing
Dry rolled corn	15	48
Corn gluten feed	40	40
Prairie hay	35	7
Supplement ¹	10	5
Nutrient analysis ²		
CP, %	16.4	22.3
RUP, % CP	30.0	36.5
TDN	73.5	83.7
Crude fat, %	4.0	3.8

¹Provided dietary concentration of 28 g/t of monensin and 10 g/t of tylosin (DM basis; Elanco Animal Health, Indianapolis, IN).

²Calculated values based on the NRC (1996) estimated values and laboratory analysis of feed ingredients.

finishing diet of 48% dry rolled corn, 40% corn gluten feed, 7% prairie hay, and 5% supplement (DM basis; Table 2). Approximately 100 d before slaughter, calves were implanted with 28 mg estradiol benzoate and 200 mg trenbolone acetate (Synovex Plus; Zoetis). Each year, all calves were slaughtered on the same day at a commercial abattoir when visually estimated to have 1.3-cm fat thickness over the 12th rib. Hot carcass weight was recorded at slaughter and carcass data was collected after a 24-h chill. Final BW was calculated using the HCW adjusted for a common dressing percentage (63%).

In yr 1, calf DMI was calculated using the DMI prediction equation established by Tedeschi et al. (2006): $DMI = 4.18 + (1.98 \times ADG) + [0.0013 \times (\text{metabolic } BW^{0.75})] + (0.019 \times EBF)$, in which **EBF** represented the empty body fat percentage. Empty body fat percentage was calculated using the equation developed by Guiroy et al. (2001), in which $EBF = 17.76107 + (11.8908 \times 12\text{th rib fat depth}) + (0.0088 \times HCW) + \{0.81855 \times [(\text{marbling score}/100) + 1]\} - (0.4356 \times LM \text{ area})$. In yr 2 and 3, calves were placed in a GrowSafe feeding system (GrowSafe Systems Ltd., Airdrie, AB, Canada) approximately 1 mo after weaning. Calf BW was measured on 2 consecutive days before GrowSafe entry and again 10 d after GrowSafe entry to account for the acclimation period to the feeding system. The average of the second 2-d BW was considered the initial feedlot entry BW and data concerning feedlot performance (BW change, DMI, and ADG) was calculated from this average BW.

Carcass Characteristics

Carcasses were chilled for 24 h before ribbing between the 12th and 13th rib interface to expose the LM and allowed to bloom for approximately 30 min before carcass data collection. Experienced USDA graders provided marbling scores. University personnel recorded HCW, percent KPH, measured LM area, and subcutaneous fat thickness. A 5.08-cm section of the LM was removed from the loin end (posterior to the ribbed surface) and transported on ice to the South Dakota State University Meat Science Laboratory (Brookings, SD).

Sections were trimmed of excess fat and bone and one 2.5-cm steak was vacuum packaged and aged for 14 d at 4°C for determination of Warner-Bratzler shear force according to American Meat Science Association (1995) guidelines. The remainder estimated values of the LM sample was minced, immersed in liquid nitrogen, and powdered using a commercial blender for determination of percent crude fat. Duplicate powdered samples (5.6 g) were weighed into dried tins, covered with dried filter papers, and dried in an oven at 100°C for 24 h. Dried samples were then placed into desiccators and samples were reweighed after cooling followed by extraction with petroleum ether in a side-arm Soxhlet extractor (Thermo Fischer Scientific, Rockville, MD) for 60 h followed by drying at room temperature for 1 h and subsequent drying in an oven at 100°C for 4 h (ether extract; as described by Bruns et al., 2004). Dried, extracted samples were placed in desiccators to cool for 1 h and then reweighed.

Economic Analysis

A partial budget analysis was conducted to evaluate the economic ramifications of maternal RUP supplementation levels. Supplementation costs were valued at actual purchase price plus a delivery charge (US\$0.07/kg). Meadow hay values were taken from Nebraska state average monthly price based on USDA Agricultural Marketing Service (USDA-AMS, 2009a, 2010a, 2011c). Calf value at weaning and feedlot purchase value were determined from Nebraska weighted average feeder cattle price reported for the given year at the time of weaning and entry into the feedlot as reported by USDA Agricultural Marketing Service (USDA-AMS, 2010b, 2011d, 2012c). 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 harvest was based on Nebraska dressed steer price for the day of harvest (USDA-AMS, 2011a, 2012a, 2013a) with grid premium and discounts applied as reported by USDA Agricultural Marketing Service (USDA-AMS, 2011b, 2012b, 2013b).

Statistical Analysis

The initial statistical model included dam treatment as the fixed effects with sex included as a covariate and sire and year included as random effects. Calf sex was a significant source of variation and, therefore, was placed in the final model as a fixed effect. Calf sex \times dam treatment interaction was tested and when not significant, removed from the model. Residual feed intake (RFI) was calculated using PROC GLM of SAS (SAS Inst. Inc., Cary, NC). Coefficients for ADG and mid BW were calculated for steers and heifers separately. Year 2 and 3 RFI was calculated with the initial period being GrowSafe entry to reimplant and the reimplant period being calculated from reimplant to slaughter to determine differences in RFI during the feedlot period. Data were considered significant if $P \leq 0.05$ and tendency was considered if $P < 0.1$ but $P > 0.05$.

RESULTS AND DISCUSSION

Prewaning and Weaning Calf Performance

Heifer calving performance data are reported elsewhere (Summers et al., 2015). Data for progeny preweaning and feedlot performance are summarized in Table 3. There was a tendency for calf weaning BW to be greater ($P = 0.14$) for calves born to HI dams compared with calves born to CON dams (259 vs. 249 ± 4 kg). Previous reports document improved weaning BW for calves born to dams offered DDGS during late gestation (Larson et al., 2009; Gunn et al., 2014). Stalker et al. (2006, 2007) and Larson et al. (2009) reported a 6- to 12-kg increase in calf weaning BW for calves born to protein supplemented dams. Similarly, Underwood et al. (2010) demonstrated that calves born to cows grazing improved pasture from d 120 to 180 of gestation resulted in increased weaning BW.

Corah et al. (1975) reported a 13-kg increase in weaning BW for calves born to heifers fed 100% of their energy requirements during late gestation compared with 65% energy requirement, and Beaty et al. (1994) reported an increase in calf weaning BW as the amount of CP fed to dams during gestation increased. Rolfe et al. (2011) used a 2×4 factorial design to determine the effect of weaning date and maternal supplementation during late gestation on calf performance. Calves born to cows grazing dormant winter range and receiving no supplement had reduced BW at approximately 7 mo of age compared with calves from cows receiving either 0.45 or 0.91 kg/d (32% CP, DM basis) of supplement during late gestation and grazing winter range or cows grazing corn residue. Conversely, Engel et al. (2008) reported no differences in weaning BW or ADG for calves born to DDGS- or soybean

hull-fed primiparous heifers. Interestingly, there was no difference in heifer calf weaning BW based on maternal diet ($P = 0.86$). Martin et al. (2007) and Funston et al. (2010) reported an increase in heifer adjusted 205-d weaning BW and actual weaning BW, respectively, for heifers born to cows supplemented with a DDGS-based supplement during late gestation. It is likely that the current study failed to report significant differences in calf weaning BW based on maternal treatment exceeding nutrient requirements in all diets, including the control (Summers et al., 2015).

Previous data suggests that increasing RUP levels in the diet during late gestation may increase milk production (Moorby et al., 1996; Greenfield et al., 1998). Van Saun et al. (1993) reported an increase in milk protein but not yield when dietary RUP levels were increased 3 wk prepartum. However, studies supplementing or feeding DDGS during late gestation in beef cattle have reported no improvements in subsequent lactation milk production. Gunn et al. (2014) reported heifers fed DDGS as an energy source had similar milk production compared with control cohorts fed an isocaloric, isonitrogenous diet. Similarly, Winterholler et al. (2012) reported no differences in milk yield based on DDGS supplementation, regardless of the level of DDGS supplement offered. Radunz et al. (2010) reported cows fed hay, limit-fed corn, or limit-fed DDGS beginning on d 209 of gestation had similar milk production levels when measured at early, mid, and late lactation. Milk production was not measured in the current study; however, the data previously mentioned would suggest no differences in milk production.

Calf Feedlot Performance

At feedlot entry, BW was 16 kg (± 18) greater ($P = 0.03$) for calves born to HI dams compared with calves born to CON, whereas feedlot entry BW was similar for HI- compared with LO-supplemented dams. Initial BW was 11 kg (± 18) greater ($P = 0.04$) for steer calves compared with heifer calves. Previous literature also reports different performance for calves based on gender. Rolfe et al. (2011) report a 17-kg increase in steer BW across treatments compared with heifer BW when steers entered the feedlot. Bailey (2006) reported a 26-kg increase ($P < 0.01$) in BW at feedlot entry for steers compared with heifers. Additionally, steers had greater DMI, ADG, HCW, and LM area compared with heifers (Bailey, 2006). Previous data also indicate similar differences in steer and heifer performance as well as alterations in the efficiency in which they deposit tissue (Hedrick et al., 1969; Ray et al., 1969; Fox and Black, 1984; Brown and Lawrence, 2010; Long et al., 2010).

Table 3. Effect of late gestation supplementation on progeny preweaning and feedlot performance

Item	Treatment ¹			Sex		SEM	P-value	
	CON	HI	LO	Steer	Heifer		Treatment	Sex
Preweaning								
<i>n</i>	34	35	31	41	59			
May calf BW, kg	99	105	102	104	101	5	0.12	0.25
Weaning wt, kg	249	259	255	258	251	4	0.14	0.18
Feedlot								
<i>n</i>								
Initial BW, kg	289 ^a	305 ^b	296 ^{a,b}	302	291	19	0.03	0.04
Reimplant BW, kg	415	423	414	428	404	9	0.31	<0.01
End BW, ² kg	600	608	602	628	579	15	0.71	<0.01
ADG, kg/d								
Initial	2.04 ^x	1.96 ^{x,y}	1.94 ^y	2.09	1.88	0.30	0.10	<0.01
Reimplant	1.73	1.71	1.72	1.83	1.61	0.04	0.88	<0.01
Total ADG	1.82	1.78	1.79	1.91	1.68	0.07	0.50	<0.01
Year 1								
DMI, ³ kg	8.39	8.18	8.27	8.50	8.05	0.13	0.49	<0.01
G:F	0.217	0.204	0.210	0.216	0.201	0.004	0.37	<0.01
RFI ⁴	0.009	0.007	-0.014	-0.010	0.011	0.008	0.20	0.08
Year 2 and 3 ⁵								
Initial ⁶								
DMI, kg	10.71	10.34	10.16	10.45	10.36	0.52	0.14	0.71
G:F	0.200	0.201	0.202	0.210	0.192	0.346	0.97	<0.01
RFI	0.180 ^a	-0.348 ^b	-0.199 ^b	-0.388	0.144	0.150	0.01	<0.01
Reimplant ⁷								
DMI, kg	11.37 ^a	10.78 ^b	10.73 ^b	11.26	10.65	0.72	0.02	0.01
G:F	0.152	0.159	0.159	0.163	0.151	0.145	0.19	<0.01
RFI	0.037 ^a	-0.278 ^b	-0.161 ^b	-0.041	-0.003	0.124	<0.01	0.81
Total ⁸								
DMI, kg	11.23 ^a	10.71 ^b	10.61 ^b	11.06	10.64	0.72	0.02	0.04
G:F	0.165	0.169	0.171	0.175	0.162	0.003	0.22	<0.01
RFI	0.292 ^a	-0.289 ^b	-0.229 ^b	-0.205	0.054	0.119	<0.01	0.06
RFI difference ⁹	0.157	0.025	0.043	0.315	-0.165	0.132	0.75	<0.01

^{a,b}Within a row, means without a common subscript differ at $P < 0.05$ for treatment.

^{x,y}Within a row, means without a common subscript tend to differ at $P < 0.10$ for treatment.

¹Dams were individually fed meadow hay (8 to 11% CP) from early November to mid February and provided no supplement (CON), 0.83 kg/d (DM basis) of a dried distillers grains with solubles-based supplement (HI), or 0.83 kg/d (DM basis) of a dried corn gluten feed-based supplement (LO) during late gestation.

²Calculated from HCW and adjusted to a common dressing percent (63.0%).

³DMI calculated in yr 1 using the prediction formula presented by Tedeschi et al. (2006): $DMI = 4.18 + (1.98 \times ADG) + [0.0013 \times (\text{metabolic BW}^{0.75})] + (0.019 \times \text{empty body fat})$.

⁴RFI = residual feed intake.

⁵Steer calves from yr 2 were placed in a GrowSafe feeding system (GrowSafe Systems Ltd., Airdrie, AB, Canada) and individual intakes recorded daily to calculate DMI, G:F, and RFI.

⁶Period from feedlot initial BW to reimplant.

⁷Period from reimplant to slaughter.

⁸Period from feedlot initial BW to slaughter.

⁹Difference in RFI between initial and reimplant periods.

In the feedlot, initial ADG tended ($P = 0.10$) to be greater for CON-born calves; however, reimplant and total ADG were similar ($P \geq 0.50$) among treatments. These numerical increases in ADG for CON born calves resulted in similar ($P \geq 0.30$) BW at reimplant and final BW among treatments. Stalker et al. (2007) and Larson et al. (2009) reported steer ADG tended

to be greater for steers born to protein-supplemented dams, whereas Underwood et al. (2010) reported that improving maternal nutrition during gestation resulted in increased ADG and tended to increase final BW. Conversely, Rolfe et al. (2011) reported no differences during the feedlot phase for ADG.

Dry matter intake did not differ ($P = 0.49$) based on maternal treatment in yr 1; however, in yr 2 and 3, DMI was greater ($P = 0.02$) for calves from CON dams during the reimplant phase, which also resulted in total DMI being greater ($P = 0.02$) for calves from CON dams compared to calves from supplemented dams (Table 3). Similarly, DMI was greater for steers than heifers in the reimplant and total feedlot phases. Although DMI was greater for calves from CON dams, there was no difference in efficiency measures as G:F based on maternal treatment. Similarly, Rolfe et al. (2011) reported no differences in G:F for calves based on maternal nutrition; however, they also reported no difference in DMI, contrary to the data in the present study.

In yr 1, RFI was similar ($P = 0.20$) based on maternal treatment; however, steer calves tended ($P = 0.08$) to have improved feed efficiency compared to their heifer cohorts. In yr 2 and 3, RFI was calculated for the initial to reimplant period, reimplant to slaughter, and entire feedlot period. Previous literature reports steer and heifer RFI can change over time, especially when animals are moved from a growing to finishing diet (Durunna et al., 2011, 2012). Residual feed intake was improved ($P = 0.01$) for calves born to supplemented dams (HI and LO) compared with CON during each phase of the feedlot as well as the entire feeding period (Table 3). However, RFI difference (calculated as reimplant RFI – initial RFI) did not differ ($P = 0.75$) between maternal treatments. Differences in yr 1 RFI data compared with yr 2 and 3 could possibly be attributed to yr 1 data being calculated based on the model proposed by Tedeschi et al. (2006) for pen fed cattle, whereas calves in yr 2 and 3 were placed in a GrowSafe system, where daily intake measurements are recorded on each calf.

Durunna et al. (2011) suggested that 58% of steers had a 0.24- to 0.38-kg/d change in RFI when switched from a growing to finishing diet. Similarly, Durunna et al. (2012) reported that RFI of 51% of heifers was reranked from period 1 to period 2, although diet did not change between the 2 periods. Similar to the report by Durunna et al. (2011), 27% of the heifers reranked between periods had a change in RFI of approximately 0.37 to 0.44 kg DM/d (Durunna et al., 2012). Although the periods measured in this study do not reflect the time in diet change from a growing to finishing diet, the time frame in which implant is changed also appears to impact RFI based on changes in RFI between periods.

Carcass Characteristics

Carcass characteristics are reported in Table 4. Age at slaughter was similar ($P \geq 0.36$) among calves based on maternal treatment and calf sex. This result

would be expected due to all cows on the study being identified as AI bred before the initiation of the study to ensure similar gestational age of calves during the supplementation phase and all calves being slaughtered on the same day. Hot carcass weight was not influenced ($P \geq 0.72$) by maternal diet during late gestation but was greater ($P < 0.01$) for steers than heifers (Table 4). Stalker et al. (2006) reported no difference in HCW for calves born to supplemented vs. nonsupplemented dams. However, Stalker et al. (2007) and Larson et al. (2009) reported increased HCW for steers born to protein-supplemented dams and Underwood et al. (2010) reported that improving maternal nutrition during gestation increased progeny HCW. In the current study, there was a maternal treatment \times calf sex interaction for marbling score. Heifers born to LO dams and steers born to CON dams had the greater ($P = 0.02$) marbling scores than heifers born to HI dams (698 ± 27 vs. 696 ± 27 vs. 599 ± 27). Radunz et al. (2012) reported an increase in marbling score for calves born to cows fed hay compared with cows limit-fed corn during late gestation but no difference in marbling score for calves from hay fed and DDGS limit-fed cows.

Empty body fat percentage and 12th rib fat thickness were reduced ($P \leq 0.05$) in LO calves compared with CON calves. Shear force was decreased ($P = 0.03$) in samples from CON calves compared with LO calves (3.47 vs. 3.95 ± 0.37 kg), suggesting improved tenderness of sample. Furthermore, shear force was reduced ($P < 0.01$) in steer compared with heifer calves (3.52 vs. 3.90 ± 0.37 kg). Similarly, crude fat tended ($P = 0.07$) to be increased in CON calves compared with LO calves but reduced ($P < 0.01$) for steers compared with heifers. Underwood et al. (2010) reported a trend for increased ether extract in LM samples from steers born to cows grazing improved pastures compared with native range during gestation. Radunz (2009) reviewed the site-specific preferences for adipocytes. Subcutaneous adipocytes prefer acetate whereas intramuscular adipocytes prefer glucose as a substrate (Smith and Crouse, 1984; Rhoades et al., 2007). Furthermore, Radunz et al. (2012) suggested that increased marbling for calves born to hay-fed dams in late gestation results from increased insulin sensitivity during gestation for hay- compared with corn-fed cows, altering fetal adipocyte development and formation. Also, plasma insulin secretion has been correlated to carcass adiposity and insulin stimulates glucose uptake and lipogenesis in adipocytes (Trenkle and Topel, 1978; Radunz et al., 2009).

The proportion of steers and heifers grading USDA small or greater and USDA modest or greater was similar ($P \geq 0.43$) for all treatments. However, heifers tended ($P = 0.09$) to have a greater proportion of

Table 4. Effect of late gestation protein supplementation on progeny carcass characteristics

Item	Treatment ¹			Sex		SEM	P-value	
	CON	HI	LO	Steer	Heifer		Treatment	Sex
<i>n</i>	34	35	31	41	59			
Age at slaughter, d	453	453	453	453	454	2	0.73	0.36
HCW, kg	378	383	379	396	365	9	0.72	<0.01
Empty body fat, ² %	31.4 ^a	30.8 ^{a,b}	29.8 ^b	30.4	30.9	2.4	0.05	0.28
Marbling score ^{3,4}	680	659	648	643	681	27	0.05	0.39
12th rib fat, cm	2.11 ^a	2.03 ^{a,b}	1.85 ^b	1.92	2.08	0.11	0.04	0.08
LM area, cm ²	84.93	87.86	88.67	88.07	86.23	3.04	0.14	0.27
Yield grade	3.82 ^a	3.65 ^{a,b}	3.43 ^b	3.61	3.65	0.50	0.05	0.84
WBSF, ⁵ kg	3.47 ^a	3.71 ^{a,b}	3.95 ^b	3.52	3.90	0.37	0.03	0.01
Crude fat, %	7.24 ^x	6.54 ^{x,y}	6.29 ^y	6.20	7.18	0.66	0.07	<0.01
Quality grade, % Sm ⁶ or greater	97	92	95	92	98		0.55	0.09
Quality grade, % Md ⁷ or greater	80	73	65	64	81		0.42	0.05

^{a,b}Within a row, means without a common subscript differ at $P < 0.05$ for treatment.

^{x,y}Within a row, means without a common subscript tend to differ at $P < 0.10$ for treatment.

¹Dams were individually fed meadow hay (8 to 11% CP) from early November to mid February and provided no supplement (CON), 0.83 kg/d (DM basis) of a dried distillers grains with solubles-based supplement (HI), or 0.83 kg/d (DM basis) of a dried corn gluten feed-based supplement (LO) during late gestation.

²Empty body fat (EBF) calculated using the prediction formula presented by Guiroy et al. (2001): $EBF = 17.76107 + (11.8908 \times 12\text{th rib fat depth}) + (0.0088 \times HCW) + \{0.81855 \times [(\text{marbling score}/100) + 1]\} - (0.4356 \times LM \text{ area})$.

³500 = small⁰.

⁴Maternal treatment \times calf sex interaction ($P < 0.05$).

⁵WBSF = Warner-Bratzler shear force.

⁶Sm = small quality grade, USDA low Choice.

⁷Md = modest quality grade, USDA average Choice.

grade USDA small or greater and had a greater ($P = 0.05$) proportion grade USDA modest or greater when compared with steer calves. Larson et al. (2009) reported a 19% increase in the proportion of steers grading USDA modest or greater for steers born to protein-supplemented dams compared with steers born to non-supplemented dams. Similarly, Radunz (2009) reported that calves born to protein-supplemented cows had increased proportions grading USDA Choice or greater. However, Stalker et al. (2006) did not report any differences in proportion of steers grading USDA Choice based on maternal protein supplementation. It should be noted that Larson et al. (2009) fed a distillers-based supplement high in RUP, whereas Stalker et al. (2006) supplemented cows with a sunflower seed meal/cottonseed meal supplement with approximately 31% RUP.

Economic Analysis

Data for economic analysis are summarized in Table 5. Maternal feed costs were reduced ($P < 0.01$) \$27 and \$24/cow for CON dams compared with LO and HI dams due to late gestation supplement costs. However, net return based on weaned calf value was not different ($P = 0.23$) among maternal treatments. Steer calves were valued \$105 greater ($P < 0.01$) than

heifer calves at weaning, resulting in an increased net return for steer calves if sold at weaning. Lack of statistical difference between treatments can be attributed to the tendency ($P = 0.14$) for calves from HI dams to be heavier at weaning compared to calves from CON dams. Feedlot purchase price tended to be greater ($P = 0.07$) for HI calves compared with CON calves due to the 16-kg difference ($P = 0.03$) in feedlot entry BW (Table 3). These data are similar to Larson et al. (2009), who also report an increase in feedlot purchase cost for calves born to protein supplemented dams. Feedlot costs are \$10 and \$11/calf greater ($P = 0.01$) for CON-born calves compared with HI- and LO-born calves, respectively. Increased costs are attributed to increased feed costs, which result from numerical increases in DMI reported in calves from CON dams (Table 3). Adjusted carcass value and net returns during the feedlot phase did not differ ($P \geq 0.82$) based on maternal treatment. These data differ from both Stalker et al. (2006) and Larson et al. (2009), who reported increased net returns for calves retained from protein-supplemented cows. Whereas Stalker et al. (2006) reported negligible increases in net difference per steer (\$0.65/animal), the authors do report an increase in net returns, which can be attributed to increased numbers of calves weaned from protein-

Table 5. Costs and returns from late gestation to weaning and weaning to slaughter associated with dams receiving no supplement or offered differing level RUP supplement

Item	Treatment ¹			Sex		SEM	P-value	
	CON	HI	LO	Steer	Heifer		Treatment	Sex
Cow-calf phase								
Hay costs, \$/cow	73.40	76.27	75.10	76.31	73.54			
Protein supplement, \$/cow	–	21.31	25.02	15.49	15.40			
Maternal feed costs, \$/cow	73.40 ^a	97.58 ^b	100.12 ^b	91.80	88.94	4.89	<0.01	0.01
Returns, \$/calf								
Weaned calf value ²	786	804	796	848	743	66	0.22	<0.01
Net return	713	706	696	756	654	68	0.23	<0.01
Feedlot phase								
Input costs, \$/animal								
Purchase cost ³	880 ^x	916 ^y	897 ^{x,y}	953	843	110	0.07	<0.01
Total feedlot costs ⁴ , \$/animal	341 ^a	331 ^b	330 ^b	339	328	12	0.02	<0.01
Returns, \$/animal								
Adjusted carcass value ⁵	1,531	1,544	1,549	1,596	1,487	82	0.82	<0.01
Net return	310	297	322	304	316	43	0.36	0.42

^{a,b}Within a row, means without a common subscript differ at $P < 0.05$ for treatment.

^{x,y}Within a row, means without a common subscript tend to differ at $P < 0.10$ for treatment.

¹Dams were individually fed meadow hay (8 to 11% CP) from early November to mid February and provided no supplement (CON), 0.83 kg/d (DM basis) of a dried distillers grains with solubles-based supplement (HI), or 0.83 kg/d (DM basis) of a dried corn gluten feed-based supplement (LO) during late gestation.

²Value of all weaned calves at weaning.

³Value of all calves at feedlot entry.

⁴Includes feed costs and yardage charged at \$0.50/d.

⁵Carcass value adjusted for discounts and premiums.

supplemented dams (Stalker et al., 2006). Larson et al. (2009) reported a \$47/steer increase in net returns for calves from protein-supplemented dams, attributed to an increased proportion of calves grading USDA Choice and increased HCW (Larson et al., 2009).

Findings in the current study differ from previously reported data for late gestation protein supplementation of multiparous cows. Studies conducted by Stalker et al. (2006, 2007), Martin et al. (2007), Larson et al. (2009), and Funston et al. (2010) used mature cows grazing winter range or corn residue, with maternal supplementation provided during late gestation. The stage of gestation in which supplementation occurred was similar to the time of supplementation in the current study. However, differences in calf performance and carcass characteristics could likely be related to control diet quality in those studies compared with the current study. The current study offered CON heifers ad libitum grass hay. As previously reported, this diet was not deficient in energy, MP, or RDP (Summers et al., 2015). Grazing cattle on dormant winter range does not meet the MP requirement for late gestating cattle; therefore, the nonsupplemented dams in the previous studies would have been in a negative energy balance, unlike CON heifers in the current study. It is possible that reducing CON heifer intake to create a negative nutrient balance, similar to that previously observed by our group in multiparous cow studies

(Stalker et al., 2006, 2007; Larson et al., 2009; Funston et al., 2010), would result in a greater fetal programming effect. Although calves from HI dams had greater initial feedlot BW compared to calves from CON dams and feedlot production and carcass characteristics were impacted by maternal nutrition, then additional research is warranted to determine the effects differing RUP supplements may have on primiparous heifers grazing low quality forages during late gestation.

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