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Fetal Programming

Timing of maternal supplementation of dried distillers grains during late gestation influences postnatal growth, immunocompetence, and carcass characteristics of *Bos indicus*-influenced beef calves

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Abstract

This 2-yr study investigated the timing of dried distillers grains (**DDG**) supplementation during the third trimester of gestation of *Bos indicus*-influenced beef cows and its impact on their offspring performance. On day 0 of each year (84 d before calving), Brangus cows (n = 84/yr; cow age = 8 ± 3 yr) were stratified by initial body weight (**BW**; 482 ± 75 kg) and body condition score (**BCS**; 5.3 ± 0.8) and assigned randomly to one of six bahiagrass (*Paspalum notatum*) pastures (experimental units; 14 cows/pasture). Treatments were assigned randomly to pasture (2 pastures/treatment/yr) and consisted of no prepartum supplementation (**CON**), 2 kg/d of DDG from day 0 to 42 (**LATE42**), or 1 kg/d of DDG from day 0 to 84 (**LATE84**). Following calving (day 84), cow–calf pairs remained in their respective pastures, and cows were offered sugarcane molasses + urea (1.82 kg of dry matter/cow/d) from day 85 until the end of the breeding season (day 224). On day 347, steer calves (n = 38/yr; 11 to 15 steers/treatment/yr) were weaned and transported to the feedlot (1,193 km). Steers were penned according to cow prepartum pasture and managed similarly until the time of harvest. BCS at calving was greater ($P < 0.01$) for LATE42 and LATE84 vs. CON cows but did not differ ($P = 0.16$) between LATE42 and LATE84 cows. Calving date, calving percentage, and birth BW of the first offspring did not differ ($P \geq 0.22$) among treatments. However, LATE42 cows calved their second offspring 8 d earlier ($P = 0.04$) compared with CON and LATE84 cows. At weaning (first offspring), LATE84 calves were the heaviest ($P \leq 0.05$), CON calves were the lightest, and LATE42 calves had intermediate BW ($P \leq 0.05$). Steer plasma concentrations of cortisol and haptoglobin and serum bovine viral diarrhea virus type-1 titers did not differ ($P \geq 0.21$) between treatments. Steer serum parainfluenza-3 titers were greater ($P = 0.03$) for LATE42 vs. CON steers, tended to be greater ($P = 0.10$) for LATE84 compared with CON steers, and did not differ ($P = 0.38$) between LATE42 and LATE84 steers. Steer feedlot BW, average daily gain, dry matter intake, and hot carcass weight did not differ ($P \geq 0.36$) between treatments. Marbling and the percentage of steers grading choice were greater ($P \leq 0.04$) for LATE42 vs. CON steers, whereas LATE84 steers were intermediate. In summary, different timing of DDG supplementation during the third trimester of gestation could be explored to optimize cow BCS and offspring preweaning growth and carcass quality.

Lay Summary

This 2-yr study evaluated the effect of the timing of dried distillers grains (DDG) supplementation during the last trimester of gestation in *Bos indicus*-influenced beef cows and the subsequent impact on their offspring. Brangus cows were allocated to one of the three prepartum treatments consisting of no prepartum supplementation, 2 kg/d of DDG for the first half of the last trimester of gestation, or 1 kg/d of DDG for the entire length of the last trimester of gestation. Prepartum supplementation, regardless of supplementation length, improved cow body condition scores at the time of calving. Calf birth weights were not affected by prepartum maternal treatment. Calves born to cows that received prepartum supplementation had greater weaning weight compared with no prepartum supplementation. However, weaning weights were improved to the greatest extent when calves were born to cows that received supplementation for the entire length of late gestation. Steer antibody response to parainfluenza-3 was improved with prepartum maternal supplementation, regardless of supplementation length. Furthermore, concentrating the total amount of supplement offered to the first half of the last trimester of gestation improved marbling and increased the percentage of steers grading choice compared with no prepartum supplementation or supplementation during the entire last trimester.

Key words: feedlot performance, fetal-programming, steer progeny

Abbreviations: ADG, average daily gain; BCS, body condition score; BVDV, bovine viral diarrhea virus type; BW, body weight; C/EBPs, CCAAT/enhancer-binding proteins; CP, crude protein; DDG, dried distillers grains; DM, dry matter; G:F, gain:feed; HCW, hot carcass weight; HPA, hypothalamic–pituitary–adrenal; IGF-1, insulin-like growth factor 1; IGF-2, insulin-like growth factor 2; IgG, immunoglobulin G; IVDOM, in vitro digestible organic matter; LMA, longissimus muscle area; NEFA, non-esterified fatty acid; NE_g, net energy for gain; NE_m, net energy for maintenance; PI_3, parainfluenza-3 virus; PPAR, peroxisome proliferator-activated receptor; TMR, total mixed ration

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Introduction

Modifications to the maternal gestational diet can have significant implications for the long-term performance of offspring (Godfrey and Barker, 2001). In beef cattle, maternal supplementation of protein and energy during the third trimester of gestation enhanced calf weaning weights (Bohnert et al., 2013; Kennedy et al., 2019), carcass weights (Stalker et al., 2007), and carcass quality grades (Larson et al., 2009; Shoup et al., 2015b) compared with calves born to cows that received no prepartum supplementation. Furthermore, managing cows to meet or exceed their nutrient requirements during the last trimester of gestation reduced the incidence of calf mortality and morbidity at feedlot entry (Corah et al., 1975; Larson et al., 2009) and improved humoral immune response to vaccination (Moriel et al., 2016). Most studies investigating the impact of supplementation of protein and energy during the third trimester of gestation on offspring postnatal performance have been conducted with *Bos taurus* cattle (Moriel et al., 2021). It is known that *B. taurus* cattle differ in regard to fetal development compared with *Bos indicus* and *B. indicus*-influenced cattle (Cooke et al., 2020). Moreover, beef cows in tropical/subtropical areas primarily graze warm-season forages (Cooke et al., 2020), which decrease in nutritive value during the autumn and winter months (Huges et al., 2010). Consequently, cows grazing warm-season forages can be deficient in nutrients and require supplemental protein and energy, particularly during the last trimester of gestation when nutrient requirements are increasing (NASEM, 2016). Hence, there is a need to investigate nutritional strategies for gestating *B. indicus*-influenced beef cows (Moriel et al., 2020, 2021; Palmer et al., 2020).

The energy and protein requirements of beef cows achieve the lowest values immediately after weaning but dramatically increase as the third trimester of gestation progresses primarily due to the exponential fetal growth (Ferrell et al., 1976; NASEM, 2016). Differentiation and maturation of fetal organs and tissues occur at specific periods of time during gestation (Lemley, 2020). In particular, the third trimester of gestation is crucial for the development of muscle fibers through hypertrophy and adipocytes via proliferation and differentiation (Du et al., 2013). To our knowledge, the specific impacts of the timing of protein and energy supplementation during the third trimester of gestation on calf postnatal growth, immune function, and carcass quality are unknown to *B. indicus*-influenced cattle. Palmer et al. (2021b) revealed that year-round vs. winter supplementation of protein and energy (both strategies offering 272 dry matter [**DM**] kg/cow/yr) impaired steer feedlot growth, innate immune response, and carcass quality, providing evidence that the timing of gestational nutrition influences production outcomes of the offspring.

It was hypothesized that the supplementation of dried distillers grains (**DDG**) to *B. indicus*-influenced cows during the third trimester of gestation, regardless of supplementation length, enhances cow prepartum body condition score (**BCS**) and calf postnatal growth, postweaning immunocompetence, and carcass quality compared with no prepartum DDG supplementation. We further hypothesized that concentrating the total amount of DDG supplementation during the first half of the third trimester of gestation, when energy and protein requirements of cows are the lowest (NASEM, 2016), leads to the greatest improvements on cow prepartum BCS without detrimental impacts to calf postnatal productive performance. Concentrating the total amount of DDG supplementation during the first half of the third trimester of gestation could be an attractive strategy to commercial cow–calf operations due to a reduction in feeding labor costs compared with supplementation offered during the entire third trimester of gestation. Thus, our objectives were to evaluate the effects of timing of DDG supplementation during the third trimester of gestation of *B. indicus*-influenced beef cows on cow BCS and physiology and offspring postnatal growth, immune function, and carcass characteristics.

Materials and Methods

This 2-yr study was conducted at the University of Florida, Institute of Food and Agricultural Sciences, Range Cattle Research and Education Center (RCREC), Ona, FL (27°23′N and 81°56′W), from August 2017 to August 2018 (year 1) and August 2018 to July 2019 (year 2). Procedures used in this study were approved by the University of Florida Animal Care and Use Committee (#201709772).

Animals and diets

Precalving (day 0 to 84) and preweaning (day 84 to 347)

At approximately 84 d before the expected calving date of each year (day 0 of years 1 and 2), multiparous, pregnant Brangus crossbred cows (n = 84 cows/yr; age = 8 ± 3 yr) were stratified by initial body weight (**BW**; 482 ± 75 kg) and BCS (5.3 ± 0.8). Brangus cows utilized in the present study were confirmed pregnant by natural service in the previous breeding season with one bull per pasture that was rotated every 28 d. Thereafter, cows were allocated randomly to one of the six bahiagrass pastures (14 cows and 9.6 ha/pasture/yr). Treatments were randomly assigned to bahiagrass pasture (2 pastures/treatment/yr) and consisted of no prepartum supplementation (**CON**), 2 kg/d of DDG DM from day 0 to 42 (**LATE42**; 84 kg of DM/cow/yr), or 1 kg/d of DDG DM from day 0 to 84 (**LATE84**; 84 kg of DM/cow/yr). The average nutrient composition of DDG (Walpole Feed and Supply, Okeechobee, FL) is presented in Table 1. The respective total weekly amount of DDG offered to LATE42 and LATE84 cows was divided into three equal amounts and offered in plastic feed bunks every Monday, Wednesday, and Friday at 0800 hours. Cows were provided free-choice access to water and were limit-fed 51 g/d of a complete commercial salt-based trace mineral and vitamin supplement containing 16.8% Ca, 4% P, 21% NaCl, 1% Mg, 60 ppm Co, 1,750 ppm Cu, 350 ppm I, 60 ppm Se, 5,000 ppm Zn, 441 IU/g Vitamin A, 33 IU/g Vitamin D_3, and 0.44 IU/g of Vitamin E (University of Florida Cattle Research Winter Mineral; Vigortone, Brookville, OH). Pastures were divided into two paddocks and grazed with a rotational stocking rate (7-d grazing and 7-d resting periods). The rotational stocking was used to increase forage accumulation and grazing efficiency (Stewart et al., 2005).

Cows were monitored daily for calving and calves were processed (weighed, tagged, and castrated if male) within the first 24 h of life but after calf consumption of maternal colostrum. From day 85 until the end of the breeding season (day 224), all cows and their calves remained in their respective pasture, and cows were offered a sugarcane (*Saccharum officinarum*) molasses + urea (Table 1; Westway Feed Products LLC, Clewiston, FL) supplement at 1.82 kg/d (DM

Table 1. Average nutritional composition (DM basis) of dried distillers grains (DDG) offered to cows from day 0 to 84 and sugarcane (*Saccharum officinarum*) molasses + urea offered to cows from day 85 until the end of the breeding season (day 224)[1]

Item[2]	DDG		Sugarcane molasses + urea[3]	
	Year 1	Year 2	Year 1	Year 2
DM, %	89.7	88.5	82.3	82.5
CP, %	33.3	32.8	21.1	22.5
Crude fat, %	—	—	1.2	2.1
ADF, %	13.6	16.7	—	—
NDF, %	34.9	35.5	—	–
TDN, %[4]	82	83	77	74
NE_m, Mcal/kg[5]	2.12	2.13	1.85	1.78
NE_g, Mcal/kg[5]	1.45	1.47	1.22	1.17
Ca, %	0.04	0.04	0.88	1.01
P, %	1.14	1.09	0.10	0.14
Mg, %	0.34	0.32	0.37	0.44
K, %	1.32	1.24	4.86	4.96
Na, %	0.23	0.30	0.10	0.15
S, %	0.84	0.54	1.08	1.31
Fe, mg/kg	78	97	209	300
Zn, mg/kg	77	78	13	45
Cu, mg/kg	7	6	4	12
Mn, mg/kg	18	17	13	40
Mo, mg/kg	1.7	1.6	1.4	1.5

[1]Treatments consisted of: CON, no maternal prepartum supplementation with DDG from day 0 to 84; LATE42, maternal supplementation of 2 kg/d of DDG from day 0 to 42; and LATE84, maternal supplementation of 1 kg/d of DDG from day 0 to 84. The total weekly DDG supplement amount was totaled and divided into three feeding events and offered every Monday, Wednesday, and Friday. All treatment groups were offered sugarcane molasses + urea at 1.82 kg/d from day 84 to 224.
[2]Samples of DDG (Walpole Feed and Supply, Okeechobee, FL) and sugarcane molasses + urea (Westway Feed Products LLC, Clewiston, FL) were collected every 28 d. Samples were composited within each year and sent in duplicate to a commercial laboratory (Dairy One Forage Laboratory, Ithaca, NY) for wet chemistry analysis. DM, dry matter; CP, crude protein; ADF, acid detergent fiber; NDF, neutral detergent fiber; NE_g, net energy for gain; NE_m, net energy for maintenance.
[3]As-fed basis: 92% liquid sugarcane molasses, 4% urea, and 4% water.
[4]Calculated based on Weiss et al. (1992).
[5]Calculated using equations proposed by NRC (2000).

basis). The total weekly amount of molasses + urea supplement was divided into two equal amounts and offered in open plastic tanks every Tuesday and Friday at 0800 hours. Tanks were placed 1 m above ground to avoid calf consumption of maternal supplements from birth until the end of the breeding season. During the breeding season (day 140 to 224), all cows and calves were offered ad libitum access to limpograss (*Hemarthria altissima*) hay (in vitro digestible organic matter [**IVDOM**] = 38.3% of DM; crude protein [**CP**] = 6.0% of DM). One Brangus bull (6 ± 3 years of age) was placed with each treatment group on day 140 and then bulls were rotated between treatment groups every 28 d from day 140 to 224. Bulls underwent a breeding soundness examination before the initiation of the breeding season and were checked daily for visual signs of injury or difficulty on mounting. Injured bulls were replaced as needed by another mature Brangus bull.

On day 224, cows and calves were administered an oral anthelmintic (2.3 mL/45 kg of BW; Safe-Guard; Merck Animal Health, Madison, NJ), and all calves were vaccinated against *Clostridium* (2 mL s.c.; Ultrabac 8, Zoetis) and respiratory pathogens, including infectious bovine rhinotracheitis, bovine viral diarrhea virus type 1 and 2 (**BVDV-1 and 2**), parainfluenza-3 (**PI_3**) virus, bovine respiratory syncytial virus, and *Mannheimia haemolytica* (2 mL s.c.; Bovi Shield Gold One Shot, Zoetis, Parsippany, NJ). All calves were weaned on day 347 at approximately 259 ± 23 d of age.

Postweaning (day 347 to slaughter)

At weaning (day 347), all steers were vaccinated against respiratory (2 mL s.c.; Bovi Shield Gold One Shot, Zoetis) and clostridial (2 mL subcutaneous; Ultrabac 8, Zoetis) pathogens. Additionally, 6 to 7 steers were randomly selected from each pasture (38 steers/yr), loaded into a commercial livestock trailer, and transported for 1,193 km to a feedlot facility at North Carolina State University (Butner Beef Cattle Field Laboratory; 36°10′N and 78°48′W) where they were housed for the remainder of the experiment. The combination of multiple stressors (weaning, transportation, and vaccination) was utilized to challenge the immune system of steers and to evaluate potential carryover effects of previous maternal supplemental treatment on offspring innate and humoral immune responses. Immediately following arrival (day 348), steers were allocated into a single 0.76-ha holding tall fescue (*Lolium arundinaceum*) pasture where they were provided free-choice access to tall fescue hay (57% total digestible nutrients [TDN] and 10.4% CP), corn silage (*Zea mays*; 58% TDN and 9.2% CP), and water for 14 d. On day 361, all steers were implanted with 200 mg of trenbolone acetate and 40 mg of estradiol (Revalor-XS; Merck Animal Health) and administered a topical (5 mL/50 kg; Ivermectin; Durvet, Blue Springs, MO) and oral (2.3 mL/45 kg; Safe-Guard; Merck Animal Health) anthelmintic. Thereafter, steers were randomly assigned to 1 of 15 (year 1) or 12 (year 2) covered concrete slatted floor pens (130 m^2 and 2 to 3 steers/pen/yr) based on previous maternal pasture distribution and provided similar management and diets until slaughter. Growing and finishing diets (Table 2) were provided once daily at 0800 hours. Steers remained on the growing diet for approximately

Table 2. Composition of the growing and finishing diet fed to steers during the feedlot phase (as-fed basis)[1]

Item	Growing	Finishing
Corn silage, %	90.00	34.00
Ground corn, %	3.42	55.33
Soybean meal, %	6.02	9.37
Limestone, %	0.36	1.06
Trace mineral salt[2], %	0.11	0.20
Rumensin 90[3], %	0.0045	0.0312
Vit ADE premix[4], %	0.0135	0.0264

[1]The growing diet was fed for 104 and 86 d in year 1 and 2, respectively. The finishing diet was fed for 111 and 95 d in year 1 and 2, respectively. An 8-d transition period between the growing and finishing diet was included in both years by increasing concentrate and decreasing corn silage by 6%, resulting in a total of 223 and 189 d on feed in year 1 and 2, respectively.
[2]Trace mineral salt premix contains 91.5% NaCl, 1% Zn, 5,000 ppm Cu, 2,500 ppm Mn, 104 ppm I, 104 ppm Se, and 72 ppm Co.
[3]Elanco Animal Health, Greenfield, IN.
[4]Vitamin A, D, and E premix contained 9,922 IU/g of vitamin A, 2,205 IU/g of vitamin D_3, and 4.41 IU/g of vitamin.

104 d in year 1 and 86 d in year 2. Steers were transitioned to the finishing diet over an 8-d period (years 1 and 2) by simultaneously increasing concentrate inclusion and decreasing corn silage concentration by 6% every day. Steers remained on the finishing diet for 111 d in year 1 and 95 d in year 2, and then, all steers were loaded into a livestock trailer on the same day and transported for 790 km to a commercial packing facility (Cargill, Wyalusing, PA). Steers were monitored daily for signs of illness by trained personnel during the growing and finishing phases. Two CON steers (one steer from years 1 and 2) were administered antibiotics to treat lacerations and one LATE42 (year 2) steer was removed from the study due to injury.

Data collection

In each year, pastures were sampled for herbage mass (HM) and forage nutritive value (CP and IVDOM) on days 0, 42, 84, 140, 224, and 283. HM was determined using the double sampling technique (Gonzalez et al., 1990). Briefly, the double sampling procedure consisted of measuring the settling height of a 0.25-m^2 aluminum disk at two locations per pasture. A metal ring, measuring the same size, was then placed in the exact location of the aluminum disk, and herbage was cut to a 2-cm stubble height with hand shears. Clipped samples were dried at 60 °C for 72 h in a forced-air oven and weighed. Settling height and DM were used to develop a regression equation. An additional 20 sites per pasture were measured for height using the 0.25-m^2 aluminum disk and averaged to determine HM with the regression equation. The herbage mass was divided by the total cow BW per pasture to determine herbage allowance (Sollenberger et al., 2005). DDG and molasses + urea samples were collected every 28 d, and samples of the total mixed ration from the growing and finishing diet were collected every 14 d for nutrient analysis. Samples of DDG and the total mixed ration (**TMR**) for the growing and finishing diet were dried at 60 °C in a forced-air oven for 72 h and ground through a 1-mm stainless steel screen (Model 4, Thomas-Wiley Laboratory Mill, Thomas Scientific).

Individual cow BCS and full BW were collected on days 0, 42, 84, 140, 164, 192, 224, and 283. Individual full BW of calves was collected at birth and on days 140, 164, 192, 224, 283, and 347. Shrunk BW of cows and calves were not utilized to avoid unnecessary physiological stress of water and food removal (Marques et al., 2016) which could interfere with calf postnatal performance (Littlejohn et al., 2016). Cows were checked daily for calving by trained personnel, and the calving date of the first and second offspring groups was recorded for each cow to determine the calving distribution. The second offspring refers to the calf conceived during the breeding season (day 140 to 224) immediately following supplementation treatments. The final percentage of pregnant cows was determined via ultrasonography by a trained veterinarian on day 283.

Blood samples (10 mL) were collected from the same 6 cows/pasture/yr (randomly selected on day 0) into sodium heparin-containing tubes (158 USP; Vacutainer, Becton Dickson, Franklin Lakes, NJ) on days 0, 42, 84, 140, 164, 192, and 224 to determine the plasma concentrations of glucose, non-esterified fatty acids (**NEFA**), and insulin-like growth factors 1 (**IGF-1**). Furthermore, blood samples collected from cows on days 0, 42, and 84 were analyzed for insulin-like growth factor 2 (**IGF-2**). Blood samples were collected from 3 male and 3 female calves/pasture/yr, within 24 h after birth, into sodium heparin-containing tubes (158 USP; Vacutainer, Becton Dickson) to assess the plasma concentrations of immunoglobulin G (**IgG**). Additional blood samples (10 mL) were collected from all feedlot steers: 1) into sodium heparin-containing tubes (158 USP; Vacutainer, Becton Dickson) on days 347, 348, 349, 354, 361, and 389 to determine the plasma concentrations of haptoglobin and cortisol; and 2) into tubes containing no additive (Vacutainer, Becton Dickson) on days 224, 347, and 389 to assess the serum neutralization antibody titers against PI_3 and BVDV-1. All blood samples from cows and calves were collected via jugular venipuncture and were immediately placed on ice following collection. All blood samples were centrifuged at 2,000 × *g* for 20 min at 4 °C. Serum and plasma were decanted into duplicate aliquots and stored at −20 °C until laboratory analysis was completed.

Individual full BW of steers was recorded immediately after unloading and arrival at the Butner Beef Cattle Field Laboratory (day 348), feedlot entry (day 361), and then every 28 d until slaughter. Daily TMR intake was determined following feedlot entry by weighing the daily amount of TMR offered at 0800 hours. Before the subsequent morning feeding, feed bunks were observed for any remaining orts. Orts were weighed and subtracted from the amount offered on the previous day. Samples of TMR were collected every 14 d to determine the DM percentage and to calculate the daily DM intake (DMI) of each feedlot pen. Hot carcass weights (**HCW**s) were recorded immediately following slaughter. All carcasses were chilled for 48 h before the determination of longissimus muscle area (**LMA**), 12th-rib fat thickness, and the percentage of kidney, pelvic, and heart fat by trained personnel. The dressing percentage of steers was calculated individually by dividing HCW by the full BW obtained at the feedlot exit.

Laboratory analysis

Hand-plucked forage samples were used to determine forage nutritive value. Samples were dried at 60 °C for 72 h in a forced-air oven and ground through a 1-mm stainless steel screen (Model 4, Thomas-Wiley Laboratory Mill, Thomas Scientific, Swedesboro, NJ). IVDOM was determined using a modification of the two-stage method as described by Moore and Mott (1974), and N concentration was determined using a micro-Kjeldahl technique proposed by Gallaher et al. (1975). CP was estimated by multiplying N concentration by 6.25. Samples of DDG and molasses + urea were composited by year and sent in duplicate to a commercial laboratory (Dairy One Forage Laboratory, Ithaca, NY) for wet chemistry analysis (Table 1). Growing and finishing diet samples were composited within each year and sent in duplicate to a commercial laboratory (Cumberland Valley Analytical Service, Waynesboro, PA) for wet chemistry analysis (Table 3).

The plasma concentrations of IGF-1 were assessed in singles using a human-specific commercial ELISA kit (SG100; R&D Systems, Inc., Minneapolis, MN) which had previously been identified to have 100% cross-reactivity with bovine IGF-1 and sensitivity of 0.056 ng/mL (Moriel et al., 2012). Moreover, the plasma concentrations of IGF-2 were determined in singles using a commercial ELISA kit (sensitivity of 7.81 ng/mL; LS-F51244; LifeSpan BioSciences, Inc., Seattle, WA). Colorimetric quantification procedures were used to assess the plasma concentrations of glucose using a commercial

Table 3. Average nutritional composition (DM basis) of the growing and finishing diet fed to steers during the feedlot phase (day 361 until slaughter)

Item[2]	Growing phase[1]		Finishing phase[1]	
	Year 1	Year 2	Year 1	Year 2
DM, %	39.7	40.8	69.2	71.4
CP, %	15.3	13.7	14.2	13.4
ADF, %	16.6	17.8	6.9	9.5
NDF, %	28.5	31.5	13.7	18.6
Ash, %	4.4	4.6	3.6	5.1
Ca, %	0.47	0.65	0.70	0.37
P, %	0.32	0.34	0.34	0.35
Mg, %	0.21	0.23	0.15	0.19
K, %	1.09	1.11	0.74	0.83
Na, %	0.11	0.11	0.13	0.13
Fe, ppm	111	219	84	95
Mn, ppm	41	68	44	65
Zn, ppm	55	62	57	70
Cu, ppm	22	21	16	18

[1]The growing diet was fed for 104 and 86 d in year 1 and 2, respectively. The finishing diet was fed for 111 and 95 d in year 1 and 2, respectively. An 8-d transition period between the growing and finishing diet was included in both years by increasing concentrate and decreasing corn silage by 6%.
[2]Growing and finishing diet samples were collected every 14 d. Samples were composited within each year and sent in duplicate to a commercial laboratory (Cumberland Valley Analytical Service, Waynesboro, PA) for wet chemistry analysis. DM, dry matter; CP, crude protein; ADF, acid detergent fiber; NDF, neutral detergent fiber.

kit (G7521; Pointe Scientific, Canton, MI). A commercial kit was used to assess the plasma concentrations of NEFA (HR Series NEFA-2; Wako Pure Chemical Industries Ltd. USA, Richmond, VA). The intra- and inter-assay coefficient of variations (CVs) for IGF-1, IGF-2, glucose, and NEFA were 2.88% and 3.25%, 2.68% and 4.50%, 2.00% and 1.75%, and 4.67% and 4.48%, respectively.

The plasma concentrations of IgG were evaluated using a bovine-specific ELISA kit (E11-118; Bethyl Laboratories, Inc., Montgomery, TX) with assay sensitivity at 0.69 ng/mL and an intra- and inter-assay CV of 5.39% and 10.73%, respectively. A chemiluminescent enzyme assay (Immulite 1000; Siemens Medical Solutions Diagnostics, Los Angeles, CA) was used to assess the plasma concentrations of cortisol with an intra- and inter-assay CV of 4.79% and 7.91%, respectively. The plasma concentrations of haptoglobin were assessed using a colorimetric assay described by Cooke and Arthington (2013) with the least detectable value of 0.03 mg/mL. The intra- and inter-assay CVs for haptoglobin were 2.29% and 2.74%, respectively.

Serum samples were shipped to the Oklahoma Animal Disease Diagnostic Laboratory (Stillwater, OK) for the determination of PI_3 and BVDV-1 antibody titers using the serum neutralization method described by Rosenbaum et al. (1970). The least and greatest tested dilutions reported for PI_3 were 1:4 and 1:512 and for BVDV-1 were 1:4 and 1:1,024, respectively. Antibody titers against PI_3 and BVDV-1 viruses were reported as the $\log_2$ of the reciprocal of the greatest dilution that achieved total protection of the cells for each serum sample. Serum neutralization titers that were <4 were considered negative for antibody and were assigned a value of 0, whereas serum neutralization titers that were ≥4 were considered positive for antibody and were assigned a value of 1. These values were used to assess the percentage of steers that were positive for seroconversion (Richeson et al., 2009) to PI_3 and BVDV-1.

Statistical analysis

All data were analyzed as a complete randomized design with maternal prepartum pasture considered the experimental unit for all dependent variables. Nonbinary data were analyzed using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC, USA, version 9.4). Forage data, cow BCS, cow and calf BW, and cow and first offspring blood data were analyzed as repeated measures and were tested for the fixed effects of maternal treatment, year, day of study, and all resulting interactions. Cow BCS and BW change, average daily gain (**ADG**), DM intake, gain:feed (**G:F**), plasma IgG, carcass data, second offspring birth weight, and calving date were analyzed for the fixed effects of maternal treatment, year, and resulting interactions. All binary data were analyzed using the GLIMMIX procedure of SAS (version 9.4). Positive seroconversion and second offspring calving distribution were analyzed as a repeated measure and tested for the fixed effects of maternal treatment, year, day of study, and resulting interactions. Cow pregnancy and calving percentages, and percentage of male calves at birth, were tested for the fixed effects of maternal treatment, year, and the resulting interaction. For all variables, prepartum pasture (maternal treatment × year) and cow (prepartum pasture) were included as random effects, except for forage measures which contained prepartum pasture (maternal treatment × year) as the sole random effect. Satterthwaite approximation was used to determine the denominator degrees of freedom for all variables analyzed. Compound symmetry was used as the covariance structure for all repeated measures as it produced the lowest Akaike information criterion. Cow (pasture) or calf (pasture) was included as subjects. Calf sex and age were included as a covariate for preweaning calf BW and cow blood parameters but were removed if $P > 0.10$. The PDIFF function was used to separate means when significance was detected. Results are reported as the least-square means with significance declared at $P \leq 0.05$ and tendencies observed at $0.05 < P \geq 0.10$.

Results

Precalving (day 0 to 84) and preweaning (day 84 to 347)

Effects of maternal treatment × year × day and maternal treatment × year were not detected ($P \geq 0.13$) for any variable analyzed herein. All forage parameters were tested for the respective forage variable on day 0. Only herbage allowance on day 0 was significant ($P = 0.03$); thus, day 0 was removed from the model for herbage mass, CP, and IVDOM. A maternal treatment × day effect ($P \geq 0.44$) was not detected for any forage variable measured. Herbage mass was not affected ($P = 0.42$) by maternal treatment (3,847, 3,573, and 3,999 ± 204 kg DM/ha for CON, LATE42, and LATE84, respectively) but a day effect was detected ($P < 0.01$; Table 4). Herbage mass was greatest ($P \leq 0.05$; Table 4) on day 42, intermediate on days 0 and 84, and least on days 224 and

Table 4. Herbage mass and allowance, crude protein, and in vitro digestible organic matter of bahiagrass (*Paspalum notatum*) pastures (2 pastures/treatment/yr)

Item[1]	Day of the study[2]						SEM	*P*-value
	0	42	84	140	224	283		Day
Herbage mass, kg dry matter (DM)/ha	4,555[c]	5,149[d]	4,753[c]	3,815[b]	2,115[a]	2,402[a]	178	<0.01
Herbage allowance, kg DM/kg body weight[3]	6.77[d]	6.37[c]	5.80[c]	4.51[b]	2.31[a]	2.33[a]	0.201	<0.01
Crude protein, % of DM	8.85[b]	7.92[a,b]	7.02[a]	7.20[a]	11.71[c]	11.99[c]	0.42	<0.01
In vitro digestible organic matter, %	43.3[d]	31.7[b]	25.3[a]	24.2[a]	37.6[c]	48.3[e]	1.66	<0.01

[1]Herbage mass was determined using the double sampling technique described by Gonzalez et al. (1990). Herbage allowance was determined by dividing the total pasture body weight by the herbage mass (Sollenberger et al., 2005). Forage samples were sent in duplicate to the University of Florida Forage Evaluation Support Laboratory (Gainesville, FL). In vitro digestible organic matter was determined using a modification of the two-stage method as described by Moore and Mott (1974), and N concentration was determined using a micro-Kjeldahl technique proposed by Gallaher et al. (1975).
[2]Day 84 corresponds to calving, day 140 the start of the breeding season, day 224 the end of the breeding season, and day 283 pregnancy diagnosis.
[3]Covariate-adjusted for day 0 ($P = 0.03$).
[a–c]Within a row, means without a common superscript differ ($P \leq 0.05$).

283. Herbage allowance was not impacted ($P = 0.32$) by maternal treatment (4.81, 4.35, and 4.89 ± 0.23 kg DM/kg BW for CON, LATE42, and LATE84, respectively). Herbage allowance was greatest ($P \leq 0.05$; Table 4) on day 0 and least on days 224 and 283. Forage concentrations of CP (8.54%, 9.53%, and 9.32 ± 0.45% of DM for CON, LATE42, and LATE84, respectively) and IVDOM (34.3%, 35.8%, and 34.9 ± 1.27% for CON, LATE42, and LATE84, respectively) did not differ ($P \geq 0.33$) among maternal treatments. Forage CP concentration was the greatest ($P \leq 0.05$; Table 4) on days 224 and 283 and the least on days 84 and 140. Forage IVDOM concentration was the least ($P \leq 0.05$; Table 4) on days 84 and 140 but the greatest on day 283.

Cow BCS and BW on day 0 did not differ among treatments ($P \geq 0.53$) but were included in the model as covariate ($P < 0.01$). A maternal treatment × day effect was observed ($P < 0.01$; Figure 1A) for cow BCS. On day 42, LATE42 and LATE84 cows had greater ($P \leq 0.04$) BCS compared with CON cows, whereas LATE42 cows tended ($P = 0.07$) to have a greater BCS compared with LATE84 cows. BCS was greater ($P \leq 0.01$) for LATE42 and LATE84 compared with CON cows on days 84, 140, 164, and 192, but BCS did not differ ($P \geq 0.16$) between LATE42 and LATE84 cows. On day 224, LATE42 cows had a greater ($P = 0.02$) BCS compared with CON cows. Additionally, LATE84 cows tended ($P = 0.07$) to have greater BCS compared with CON cows but LATE84 and LATE42 cows did not differ ($P = 0.42$) in BCS on day 224. On day 283, there was a tendency ($P = 0.07$) for LATE42 cows to have a greater BCS compared with CON cows. However, BCS did not differ ($P \geq 0.18$) between treatments on day 283. Cow BCS change from day 0 to 42, and it was greatest ($P < 0.01$; Table 5) for LATE42 cows, intermediate for LATE84 cows, and the least for CON cows. From day 42 to 84, LATE42 and LATE84 cows had greater ($P \leq 0.01$) BCS change compared with CON cows. Lastly, LATE42 cows experienced a greater ($P = 0.02$) reduction in BCS from day 84 to 140 compared with CON cows, with LATE84 cows being intermediate. A maternal treatment × day effect was detected ($P = 0.01$; Figure 1B) for cow BW. On day 42, LATE42 cows had a greater ($P < 0.01$) BW compared with CON cows, whereas LATE84 cows tended to have a greater ($P = 0.07$) BW vs. CON cows. Cow BW did not differ ($P = 0.23$) between LATE42 and LATE84 cows on day 42. Cow BW was the greatest ($P \leq 0.03$) for LATE42 vs. CON cows, with LATE84 cows being intermediate on days 84, 140, and 283. Cow BW change did not differ among treatments throughout the study ($P = 0.14$; Table 5).

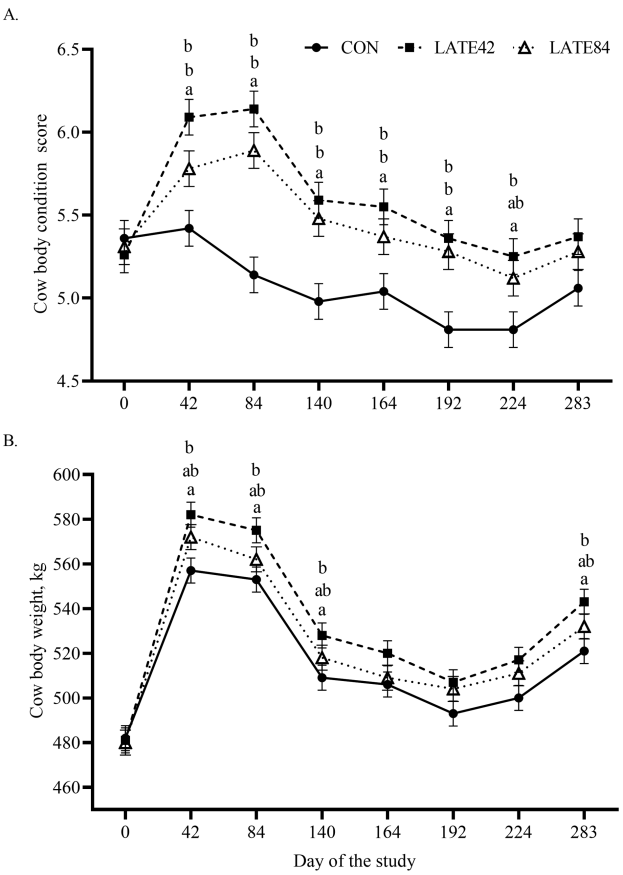

Figure 1. Body condition score (BCS; A) and body weight (BW; B) of *Bos indicus*-influenced cows from day 0 to pregnancy diagnosis on day 283 (2 pastures/treatment/yr). Calving initiated on day 84 and breeding season initiated on day 140. Treatments consisted of no maternal prepartum supplementation with dried distillers grains (DDG) from day 0 to 84 (CON), maternal supplementation of 2 kg/d of DDG from day 0 to 42 (LATE42), or maternal supplementation of 1 kg/d of DDG from day 0 to 84 (LATE84). Cow BCS and BW on day 0 did not differ among treatments ($P \geq 0.53$) but were included in the model as covariate ($P < 0.0001$). A treatment × day effect was detected ($P < 0.01$) for cow BCS and BW.
[a,b]Within day, means without common superscripts differ ($P \leq 0.05$).

Calving percentage, calving date, and birth BW of the first offspring did not differ ($P \geq 0.38$; Table 6) among maternal treatments. Calf sex and calving date were included in the model as a covariate ($P < 0.10$) for birth BW of the first offspring. Calf plasma concentrations of IgG and percentage of pregnant cows on day 283 did not differ ($P \geq 0.44$; Table 6) among maternal treatments. Calving percentage, percentage of male calves at birth, and birth BW of the second offspring did not differ ($P \geq 0.57$) among maternal treatments (Table 6). A treatment × day effect tended ($P = 0.07$) to be detected for calving distribution of the second calf crop (Figure 2). A greater ($P \leq 0.05$) percentage of LATE42 cows calved from day 434 to 455 compared with CON and LATE84 cows. Thereafter, a greater ($P = 0.01$) percentage of LATE42 cows calved on day 462 compared with CON cows, with LATE84 cows being intermediate. The calving percentage did not differ ($P \geq 0.11$) among maternal treatments from day 469 to 511.

All cow plasma variables were tested for the effect of calf sex; however, calf sex was not significant ($P \geq 0.12$) for any cow plasma variable analyzed and thus it was removed from the model. All maternal plasma data were covariate-adjusted ($P < 0.01$) for the respective plasma concentrations on day 0. There was a tendency ($P = 0.10$) for a maternal treatment × day effect for cow plasma glucose concentrations (Figure 3). Plasma glucose concentrations were greater ($P = 0.02$) for LATE42 vs. LATE84 cows on day 164, with CON cows being intermediate. A maternal treatment × day effect was not detected ($P = 0.65$) for cow plasma IGF-1 concentration. However, there was a tendency ($P = 0.10$; Table 7) for maternal treatment effect for cow plasma IGF-1 concentrations, which were greater ($P \leq 0.05$) for LATE42 and LATE84 vs. CON cows. Effect of day was detected ($P < 0.01$) for cow plasma IGF-1 concentrations, which were the greatest ($P \leq 0.05$) on day 42 but decreased on days 84, 140, and 224. Effects of maternal treatment × day and maternal treatment effects were not detected ($P \geq 0.57$; Table 7) for cow plasma IGF-2 concentrations. Cow plasma IGF-2 concentrations were the greatest ($P \leq 0.05$) on days 0 and 42 but decreased on day 84. A maternal treatment × day effect was not observed ($P = 0.43$) for cow plasma NEFA concentrations. There was a tendency ($P = 0.10$; Table 7) for a maternal treatment effect for cow plasma NEFA concentrations, which were greater ($P = 0.03$) for LATE42 vs. LATE84 cows, whereas CON cows were intermediate (0.44, 0.37, 0.41 ± 0.021 mEq/L for LATE42, LATE84, and CON, respectively). Cow plasma NEFA concentrations were the greatest ($P \leq 0.05$) on days 84 and 140.

Calf preweaning BW gain and ADG were covariate-adjusted ($P \leq 0.05$) for calf sex and age. A maternal treatment × day effect was detected ($P = 0.01$; Table 8) for preweaning BW of the first offspring. First offspring BW did not differ ($P \geq 0.31$) among maternal treatments on day 140. On day 164, first offspring BW tended ($P = 0.08$) to be greater for LATE84 vs. CON calves, whereas BW of LATE42 calves did not differ ($P \geq 0.39$) compared with CON or LATE84 calves. First offspring BW was greater ($P \leq 0.05$) for LATE84 vs. CON calves on days 192, 224, and 283. On day 192, the BW of LATE42 calves did not differ ($P \geq 0.22$) from CON or LATE84 calves. However, on days 224 and 283, LATE42 calves tended ($P = 0.08$) to have a greater BW vs. CON calves but did not differ ($P \geq 0.15$) from LATE84 calves. On day 347, LATE84 calves had greater ($P \leq 0.05$) BW compared with CON and LATE42 calves, whereas LATE42 calves had greater BW ($P \leq 0.05$) compared with CON calves. First offspring ADG from birth to weaning was greater ($P = 0.01$; Table 8) for LATE84 vs. CON calves and tended ($P = 0.08$) to be greater for LATE84 vs. LATE42 calves. ADG from birth to weaning did not differ ($P = 0.43$) for LATE42 compared with CON calves.

Postweaning (day 347 to slaughter)

Maternal treatment × day and maternal treatment effects were not observed ($P \geq 40$) for steer plasma concentrations of cortisol or haptoglobin (Table 9). Effects of day were detected ($P < 0.01$) for plasma concentrations of cortisol (2.24, 2.69, 2.48, 1.99, 2.12, and 1.60 ± 0.14 µg/dL on days 347, 348, 349, 354, 361, and 389, respectively) and haptoglobin (0.05, 0.42, 0.86, 0.18, 0.09, and 0.07 ± 0.03 mg/mL on days 347, 348, 349, 354, 361, and 389, respectively). Plasma haptoglobin concentrations peaked on day 349 and returned to baseline on days 361 and 389. All steers were serum negative for BVDV-1 and PI_3 viruses on day 227. Maternal treatment × day and maternal treatment effects were not detected ($P \geq 0.21$; Table 9) for serum BVDV-1 titers and seroconversion. A maternal × day effect was not observed ($P = 0.51$) for steer serum PI_3 titers; although, there was a tendency ($P = 0.07$) for a maternal treatment effect. Steer serum PI_3 titers were greater ($P = 0.03$) for LATE42 vs. CON steers and tended to be greater ($P = 0.10$) for LATE84 vs. CON steers. However, steer serum PI_3 titers did not differ ($P = 0.38$) between LATE42 and LATE84 steers. A maternal treatment × day effect was detected ($P = 0.01$) for positive seroconversion against PI_3, which was greater ($P \leq 0.05$) for LATE42 and LATE84 vs. CON steers on day 347 (Table 9). On day 389, positive seroconversion against PI_3 did not differ ($P \geq 0.84$) among maternal treatments.

Steer feedlot BW, ADG, and DMI did not differ ($P \geq 0.36$; Table 10) among maternal treatments. G:F did not differ ($P = 0.89$; Table 10) among maternal treatments during the growing phase but was greater ($P \leq 0.05$) for CON steers during finishing and the total feedlot period compared with LATE42 and LATE84 steers. Steer HCW, dressing percentage, 12th-rib fat thickness, LMA, percent of kidney, pelvic, and heat (KPH), and yield grade did not differ ($P \geq 0.12$; Table 11) among maternal treatments. Marbling score was greater ($P = 0.02$; Table 11) for LATE42 steers compared with CON steers. However, marbling scores did not differ ($P \leq 0.25$) between LATE84 steers and CON or LATE42 steers. Similarly, the percentage of carcasses grading average choice was greater ($P = 0.04$; Table 11) for LATE42 vs. CON steers, and LATE84 steers did not differ ($P \geq 0.17$) between CON or LATE42 steers. The percentage of steers grading low choice and select did not differ ($P \geq 0.17$) among maternal treatments.

Discussion

Precalving (day 0 to 84) and preweaning (day 84 to 347)

Maternal performance

Beef cows in tropical/subtropical environments predominantly graze warm-season forages (Cooke et al., 2020). However, the energy and protein values of warm-season forages decrease in the autumn and winter months (Hughes et al., 2010). This reduction in nutritive value coincides with the third trimester of gestation when the energy requirements of beef cows are increasing to meet the demand of the

Table 5. Body condition score (BCS) and body weight (BW) change of multiparous *Bos indicus*-influenced beef cows offered no prepartum supplementation (CON) or dried distillers grains (DDG) supplementation during the first half (LATE42) or entire third trimester of gestation (LATE84; 2 pastures/treatment/yr)

Item	Maternal treatment[1]			SEM	*P*-value
	CON	LATE42	LATE84		Treatment
Cow BCS change					
Day 0 to 42	0.07[a]	0.82[c]	0.46[b]	0.07	<0.01
Day 42 to 84	−0.30[a]	0.13[b]	0.13[b]	0.08	0.02
Day 84 to 140	−0.15[b]	−0.62[a]	−0.41[a,b]	0.10	0.06
Day 140 to 164	0.06	−0.04	−0.11	0.10	0.49
Day 164 to 192	−0.23	−0.19	−0.09	0.08	0.48
Day 192 to 224	0.00	−0.13	−0.16	0.08	0.34
Day 224 to 283	0.28	0.13	0.16	0.12	0.63
Cow BW change, kg					
Day 0 to 42	74	100	92	8.1	0.15
Day 42 to 84	−4	−5	−10	11.3	0.91
Day 84 to 140	−44	−48	−43	4.9	0.83
Day 140 to 164	−2	−9	−9	2.7	0.21
Day 164 to 192	−13	−13	−6	2.6	0.14
Day 192 to 224	7	11	8	2.9	0.63
Day 224 to 283	22	26	21	5.6	0.83

[1]Treatments consisted of: CON, no maternal prepartum supplementation with DDG from day 0 to 84; LATE42, maternal supplementation of 2 kg/d of DDG from day 0 to 42; and LATE84, maternal supplementation of 1 kg/d of DDG from day 0 to 84. Day 84 corresponds to calving, day 140 the start of the breeding season, day 224 the end of the breeding season, and day 283 pregnancy diagnosis.
[a–c]Within a row, means without common superscript differ ($P \leq 0.05$).

rapidly growing fetus (NASEM, 2016). Therefore, cows primarily grazing warm-season forages may experience nutrient restriction and require supplemental protein and energy (Kunkle et al., 1999) during the third trimester of gestation. In the present study, there were no maternal treatment effects observed for herbage mass and allowance, and forage concentrations of IVDOM and CP. Herbage allowance during the study was sufficient (1.40 kg DM/kg BW) to allow for ad libitum intake of beef cattle grazing bahiagrass pastures (Inyang et al., 2010). Forage IVDOM and CP concentrations were below the energy and protein requirements of pregnant beef cows during late gestation or early lactation (NASEM, 2016), which explains the BCS loss of CON cows from day 42 to 140, indicating that CON cows were nutrient-restricted during the last 42 d of gestation until the start of the breeding season.

Prepartum BCS of cows increased linearly with greater amounts of DDG supplementation (0.77, 1.54, or 2.31 kg/d of DDG) offered during the third trimester of gestation (Winterholler et al., 2012). In agreement with our hypothesis, cows receiving 2 kg/d of DDG from day 0 to 42 (LATE42 cows) had a greater increase (+0.36) in BCS during the first half of the third trimester of gestation compared with those offered 1 kg/d of DDG supplementation (LATE84 cows). At the start of calving season (day 84), the BCS of LATE42 and LATE84 cows did not differ. Nonetheless, cows supplemented with DDG during the third trimester of gestation, regardless of supplementation length, had greater BCS before and at the time of calving compared with CON cows. Likewise, cows fed low-quality meadow hay (6.4% CP) and offered 0.9 kg/d of a DDG supplement during the third trimester of gestation had greater BCS at calving (+0.20) compared with cows that did not receive DDG supplementation (Bohnert et al., 2013).

Cow BCS at the time of calving is a major controlling factor of postpartum interval and pregnancy rate in the subsequent breeding season (Richards et al., 1986). Despite the differences observed in cow BCS at the time of calving, DDG supplementation during late gestation did not impact the percentage of pregnant cows on day 283. Our findings are supported by previous research that found no differences in subsequent pregnancy rates when offered prepartum supplementation of protein and/or energy (Stalker et al., 2007; Larson et al., 2009; Bohnert et al., 2013). Despite the lesser BCS at the time of calving, CON cows calved slightly above the minimum acceptable calving BCS (≥5.0) to maintain adequate reproductive performance in the subsequent breeding season (Hess et al., 2005). Cows on the LATE42 and LATE84 treatments had greater BCS throughout the breeding season compared with CON cows. However, it is important to note that BCS change from the initiation to the end of the breeding season did not differ among maternal treatments. Additionally, BCS change throughout the breeding season was minimal for CON cows (−0.17 from start to end of breeding season), further explaining the lack of differences in pregnancy rates among maternal treatments. The primary objective of this study was to determine the effect of maternal treatment on calf postnatal performance. Thus, this study may lack the statistical power to determine maternal treatment effects on cow reproductive performance and readers should take this into consideration when interpreting results pertaining to cow reproduction.

All cows lost BCS from calving until the start of the breeding season. Though not statistically different, BCS loss of LATE42 cows was numerically greater (−0.62 vs. −0.41) from calving to the start of the breeding season compared with LATE84 cows. The greater average plasma NEFA concentrations for LATE42 compared with LATE84 cows are likely attributed to the numerically greater BCS loss from calving to the start of the breeding season (Roche et al., 2015) compared with CON and LATE84 cows, as mobilization of fat reserves leads to elevated plasma NEFA concentrations (Van der Drift et al., 2012; Schäff et al., 2013). Ciccioli et al. (2003) reported greater plasma NEFA concentrations in cows fed a high-energy diet following parturition vs. cows on a moderate-energy diet; however, cows on the high-energy diet had a reduction in the number of days from parturition to the first estrus. Thus, the authors suggested that the elevated plasma NEFA concentrations could have signified greater mobilization of energy for reproduction (Ciccioli et al., 2003). In the present study, we observed that LATE42 cows calved earlier in the subsequent calving season compared with LATE84 or CON cows. Moreover, LATE42 cows had greater plasma concentrations of glucose approximately 24 d after the start of the breeding season. Glucose concentrations are often reduced during periods of nutritionally induced anestrous (Richards et al., 1989), supporting that LATE42 cows were in a better nutritional status during the breeding season leading to earlier pregnancy compared with CON and LATE84 cohorts.

Maternal diet during pregnancy impacts circulating levels of IGF-1 and IGF-2 (Perry et al., 2002; Sullivan et al., 2009). The average plasma IGF-1 concentrations were increased

Table 6. Reproductive performance of *Bos indicus*-influenced beef cows offered no prepartum supplementation (CON) or dried distillers grains (DDG) supplementation during the first half (LATE42) or entire third trimester of gestation (LATE84; 2 pastures/treatment/yr)

Item[2]	Maternal treatment[1]			SEM	*P*-value
	CON	LATE42	LATE84		Treatment
First offspring					
Calving date, day of the study	88	87	84	3.3	0.68
Calving, % of total cows	98.2	97.8	94.4	2.43	0.48
Calf birth BW[3], kg	35	37	37	0.83	0.38
Calf plasma IgG[4], mg/mL	52.4	45.1	46.5	4.77	0.44
Second offspring					
Pregnant cows on day 283, % of total	90.1	88.0	91.8	3.65	0.75
Calving date, day of the study	457[b]	448[a]	456[b]	2.7	0.04
Calving, % of total cows	89.8	89.2	88.1	4.60	0.96
Male calves at birth, %	52	51	61	7.4	0.57
Calf birth BW, kg	36	37	36	2.7	0.63

[1]Treatments consisted of: CON, no maternal prepartum supplementation with DDG from day 0 to 84; LATE42, maternal supplementation of 2 kg/d of DDG from day 0 to 42; and LATE84, maternal supplementation of 1 kg/d of DDG from day 0 to 84.
[2]First offspring consists of calves that were in-utero when dietary treatments were provided to cows during the third trimester of gestation. The second offspring consists of calves that were conceived during the breeding season (day 140 to 224).
[3]Covariate-adjusted for calf sex and calving date ($P \leq 0.10$). BW, body weight.
[4]Blood samples were collected from calves via jugular venipuncture within 24 h of birth. IgG, immunoglobulin G.
[a,b]Within a row, means without common superscript differ ($P \leq 0.05$).

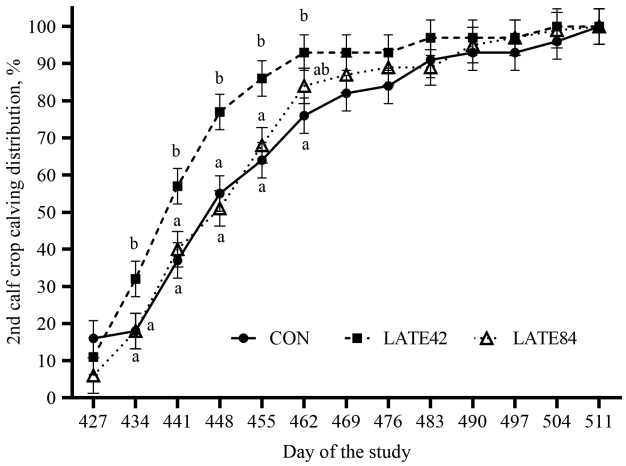

Figure 2. Calving distribution of the second offspring (2 pastures/treatment/yr). Treatments consisted of no maternal prepartum supplementation with dried distillers grains (DDG) from day 0 to 84 (CON), maternal supplementation of 2 kg/d of DDG from day 0 to 42 (LATE42), or maternal supplementation of 1 kg/d of DDG from day 0 to 84 (LATE84). A treatment × week effect was detected ($P = 0.07$) for calving distribution of the second offspring. [a,b]Within week, means without common superscripts differ ($P \leq 0.05$).

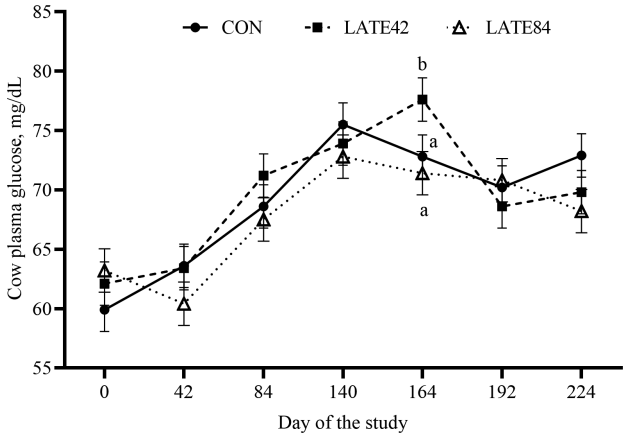

Figure 3. Plasma glucose concentrations of *Bos indicus*-influenced cows from day 0 to pregnancy diagnosis on day 283 (2 pastures/treatment/yr). Calving initiated on day 84 and breeding season initiated on day 140. Treatments consisted of no maternal prepartum supplementation with dried distillers grains (DDG) from day 0 to 84 (CON), maternal supplementation of 2 kg/d of DDG from day 0 to 42 (LATE42), or maternal supplementation of 1 kg/d of DDG from day 0 to 84 (LATE84). Plasma glucose concentrations on day 0 did not differ among treatments ($P \geq 0.19$) but were included in the model as covariate ($P = 0.0004$). A treatment × day effect was detected ($P < 0.10$) for plasma glucose concentrations. [a,b]Within day, means without common superscripts differ ($P \leq 0.05$).

with DDG supplementation, regardless of supplementation length, compared with no DDG supplementation (CON). Plasma IGF-2 concentrations of cows were only assessed during the prepartum period (days 0, 42, and 84) as IGF-2 increases with gestation length (Kubota et al., 1992). However, prepartum plasma concentrations of IGF-2 were not influenced by maternal treatment. The influence of maternal nutrition on circulating IGF-1 and IGF-2 concentrations is variable. For example, protein supplementation during the first and second trimesters of gestation increased the plasma concentrations of IGF-1 and IGF-2 in pregnant cows (Perry et al., 2002; Sullivan et al., 2009). In contrast, maternal plasma IGF-1 concentrations did not differ between pregnant cows offered a high- (12% CP) vs. low-protein diet (6% CP) during the last 120 d of gestation (López Valiente et al., 2018). The discrepancy between studies could be due to the differences in the amount of supplement offered or the timing at which supplementation was offered to cows during gestation.

Cow plasma concentrations of glucose did not differ between treatments prior to calving (days 42 and 84). In support, plasma glucose concentrations on day 210 of gestation

Table 7. Plasma concentrations of insulin-like growth factor 1 (IGF-1) and 2 (IGF-2), and non-esterified fatty acids (NEFA) of *Bos indicus*-influenced beef cows offered no prepartum supplementation (CON) or dried distillers grains (DDG) supplementation during the first half (LATE42) or entire third trimester of gestation (LATE84; 2 pastures/treatment/yr)

Item[2]	Maternal treatment[1]			SEM	*P*-value	
	CON	LATE42	LATE84		Treatment	Treatment × day
Plasma IGF-1, ng/mL	36.7[a]	39.5[b]	39.9[b]	1.15	0.10	0.65
Plasma IGF-2, ng/mL	1,053	969	1,107	185	0.89	0.57
Plasma NEFA, mEq/L	0.41[a,b]	0.44[b]	0.37[a]	0.021	0.10	0.43

[1]Treatments consisted of: CON, no maternal prepartum supplementation with DDG from day 0 to 84; LATE42, maternal supplementation of 2 kg/d of DDG from day 0 to 42; and LATE84, maternal supplementation of 1 kg/d of DDG from day 0 to 84.
[2]Plasma concentrations of IGF-1, IGF-2, and NEFA on day 0 did not differ ($P \geq 0.82$) among treatments. Covariate-adjusted for the respective plasma concentrations on day 0 ($P < 0.01$).
[a,b]Within a row, means without common superscript differ ($P \leq 0.05$).

Table 8. Preweaning body weight (BW) gain of the first offspring born to *Bos indicus*-influenced beef cows offered no prepartum supplementation (CON) or dried distillers grains (DDG) supplementation during the first half (LATE42) or entire third trimester of gestation (LATE84; 2 pastures/treatment/yr)

Item	Maternal treatment[1]			SEM	*P*-value	
	CON	LATE42	LATE84		Treatment	Treatment × day
Preweaning BW[2], kg						
Day 140	84	86	88	2.8	0.05	0.01
Day 164	100	103	107			
Day 192	121[a]	124[a,b]	129[b]			
Day 224	149[a]	156[a,b]	160[b]			
Day 283	210[a]	217[a,b]	222[b]			
Day 347	255[a]	261[b]	269[c]			
Preweaning ADG[2], kg/d	0.85[a]	0.86[a,b]	0.90[b]	0.01	0.04	—

[1]Treatments consisted of: CON, no maternal prepartum supplementation with DDG from day 0 to 84; LATE42, maternal supplementation of 2 kg/d of DDG from day 0 to 42; and LATE84, maternal supplementation of 1 kg/d of DDG from day 0 to 84. Day 84 corresponds to calving, day 140 the start of the breeding season, day 224 the end of the breeding season, day 283 is pregnancy diagnosis, and day 347 is weaning.
[2]Covariate-adjusted for calf sex and age ($P < 0.05$). ADG, average daily gain.
[a–c]Within a row, means without common superscript differ ($P \leq 0.05$).

did not differ between cows limit-fed DDG at 4.1 kg/d compared with cows fed ad libitum intake of orchardgrass hay (Radunz et al., 2010). Overall plasma IGF-1 concentrations were greater for LATE42 and LATE84 cows; thus, it is plausible that there was a greater uptake of glucose by the fetus (Sferruzzi-Perri et al., 2006). However, it is also possible that supplementing cows with DDG at either 1 kg/d for the entire third trimester of gestation or 2 kg/d for the first half of the third trimester of gestation did not provide sufficient precursors for increased gluconeogenesis. Supplementation of DDG at 0%, 0.2%, 0.4%, and 0.8% of BW in heifers grazing small-grain pastures did not alter propionate concentrations (Islas and Soto-Navarro, 2011). In the present study, DDG DM supplementation was offered at either 0.2% (LATE84) or 0.4% (LATE42) of BW, suggesting that the amount of DDG supplementation offered may have not been sufficient to increase propionate production in the rumen and gluconeogenesis. Additionally, blood collections were obtained starting at 0800 hours (before morning supplementation) to ensure all sample collections and animal processing and return to their respective pastures were conducted before the hottest hours of the day (thermal humidity index at the research site often achieves 90 or above by 1 p.m.). The peak of ruminal fermentation and end products release after concentrate intake occurs within 3 to 4 h after morning supplementation (Artioli et al., 2015; Silva et al., 2018). Therefore, the timing of blood collection could also partially explain the lack of maternal treatment effects on prepartum plasma glucose concentrations.

Offspring performance

Birth BW of the first offspring did not differ among maternal treatments. The impact of prepartum DDG supplementation during late gestation on offspring birth BW has been variable with some studies reporting an increase (Radunz et al., 2012; Winterholler et al., 2012; Bohnert et al., 2013; Kennedy et al., 2016) or no effects (Shoup et al., 2015a; Summers et al., 2015b; Wilson et al., 2015) on offspring birth BW. Fetal growth is dependent on the amount of nutrients available (Bauer et al., 1998) with glucose and amino acids largely supplying the substrates necessary for fetal growth (Bell, 1995). A 40% nutrient restriction in ewes decreased maternal plasma glucose concentrations by 12%, fetal plasma glucose concentrations by 16%, and reduced birth BW by 13% (Vonnahme, 2012). Hence, alterations in maternal nutrition impact nutrient availability to the fetus and significantly influence birth weights of the offspring. In the present study, prepartum plasma glucose concentrations of cows did not differ among maternal treatments, which could partially explain the lack of maternal treatment differences in calf birth BW.

Table 9. Plasma and serum data of steers born to *Bos indicus*-influenced beef cows offered no prepartum supplementation (CON) or dried distillers grains (DDG) supplementation during the first half (LATE42) or entire third trimester of gestation (LATE84; 2 pastures/treatment/yr)

Item[2]	Maternal treatment[1]			SEM	*P*-value	
	CON	LATE42	LATE84		Treatment	Treatment × day
Plasma cortisol, µg/dL	2.13	2.29	2.15	0.16	0.76	0.79
Plasma haptoglobin, mg/mL	0.25	0.30	0.28	0.02	0.40	0.78
Serum BVDV-1[3]						
Titers, $\log_2$	3.46	4.41	3.91	0.38	0.21	0.87
Seroconversion, % total	78	85	88	7.2	0.64	0.27
Serum PI_3[3]						
Titers, $\log_2$	2.53[a]	4.30[b]	3.73[a,b]	0.44	0.07	0.51
Seroconversion, % total						
Day 347	21[a]	63[b]	54[b]	11	0.32	0.01
Day 389	80	82	83			

[1]Treatments consisted of: CON, no maternal prepartum supplementation with DDG from day 0 to 84; LATE42, maternal supplementation of 2 kg/d of DDG from day 0 to 42; and LATE84, maternal supplementation of 1 kg/d of DDG from day 0 to 84.
[2]On day 224, calves received an oral anthelmintic (2.3 mL/45 kg of body weight; Merck Animal Health, Madison, NJ) and were vaccinated against BVDV, PI_3, and *Mannheimia haemolytica* (2 mL s.c.; Bovi Shield Gold One Shot, Zoetis, Parsippany, NJ) and *Clostridium* (2 mL s.c.; Ultrabac 8, Zoetis). Steers were revaccinated at weaning (day 347) with Bovi Shield Gold One Shot (2 mL s.c.; Zoetis) and Ultrabac 8 (2 mL s.c.; Zoetis). Abbreviations: BVDV, bovine viral diarrhea virus type; PI_3, parainfluenza-3 virus.
[3]Serum PI_3 and BVDV-1 titers are reported as the $\log_2$ of the greatest dilution of serum that provided complete protection of cells. Steers were considered seropositive if they had serum neutralization values ≥ 4. All steers were seronegative for BVDV-1 and PI_3 viruses on day 224.
[a,b]Within a row, means without common superscript differ ($P \leq 0.05$).

The IGF system is an integral factor regulating the partitioning of nutrients between the mother and the fetus. In pregnant guinea pigs, infusion of exogenous IGF-1 and IGF-2 during early pregnancy enhanced placental transfer and glucose utilization by fetal tissue (Sferruzzi-Perri et al., 2006). Cows offered DDG supplementation, regardless of supplementation length, had greater overall plasma IGF-1 concentrations compared with CON cows, whereas plasma IGF-2 concentrations did not differ among maternal treatments. Despite the elevated plasma IGF-1 concentrations in LATE42 and LATE84 cows, the birth BW of the first offspring did not differ among treatments. It is possible that the increase in circulating IGF-1 may not have been sufficient to enhance glucose uptake by the fetus. Additionally, plasma IGF-1 could have been directed to other maternal tissues which would support the increased prepartum BCS in LATE42 and LATE84 cows. In support, maternal plasma concentrations of IGF-1 and IGF-2 have not previously been correlated to birth weights in the ovine or bovine model (Gluckman and Barry, 1988; Sullivan et al., 2009). Moreover, nutrient availability to the fetus, and consequently fetal growth, is also dependent on uterine and umbilical blood flow (Reynolds and Redmer, 1995). Supplementation of DDG in combination with grazing low-quality forages during late gestation decreased total uterine blood flow but did not influence calf birth weights (Mordhorst et al., 2017). Thus, alterations to endocrine signaling and nutrient exchange could all provide potential explanations for discrepancies reported regarding offspring birth BW.

Maternal nutrition during late gestation impacts calf survivability (Corah et al., 1975). However, prepartum supplementation of DDG did not impact IgG concentration in the colostrum (Kennedy et al., 2019). Supplementation of DDG, regardless of length, did not affect plasma concentrations of IgG in the present study, corroborating with previous studies (Bohnert et al., 2013; Kennedy et al., 2019). Additionally, calves born to cows that were fed 57% of their nutrient requirements had similar concentrations of serum IgG compared with calves born to cows fed 100% of their nutrient requirements (Hough et al., 1990). It is plausible that the lack of maternal treatment effects on calf plasma IgG concentrations at birth are correlated with altered intestinal immunoglobulin absorption capacity. Calves born to nutrient-restricted cows may be programmed to absorb nutrients more efficiently compared with calves born to cows that receive adequate nutrition during gestation as fetuses from nutrient-restricted cows have increased small intestine length and larger villi (Duarte et al., 2013). Nonetheless, data reported herein demonstrated that calf passive immune transfer following birth did not differ among maternal treatments.

Calves that were born to cows that received DDG supplementation for the entire third trimester of gestation (LATE84) had the greatest preweaning BW gain, resulting in a 14-kg BW advantage compared with CON calves. Earlier research has demonstrated that dam supplementation with either protein or energy during the third trimester of gestation increased calf weaning weights compared with cohorts whose dams received no prepartum supplementation (Stalker et al., 2006, 2007; Larson et al., 2009; Bohnert et al., 2013; Kennedy et al., 2019; Moriel et al., 2020; Palmer et al., 2020). Supplementation with DDG for only the first half of the third trimester of gestation (LATE42) also enhanced calf preweaning BW compared with CON calves but to a lesser extent compared with LATE84 calves (6 vs. 14 kg of added weaning BW for LATE42 and LATE84 calves, respectively). The added benefit in weaning weights from prepartum supplementation of DDG, regardless of supplementation length, is attributed to the positive gain in cow BCS during the third trimester of gestation compared with no prepartum supplementation (CON). Increasing cow BCS from 4 to 6 (scale of 1 to 9) during the third trimester of gestation resulted in greater calf weaning weights compared with maintaining cows at an

Table 10. Feedlot performance of steers born to *Bos indicus*-influenced beef cows offered no prepartum supplementation (CON) or dried distillers grains (DDG) supplementation during the first half (LATE42) or entire third trimester of gestation (LATE84; 2 pastures/treatment/yr)

Item[2]	Maternal treatment[1]			SEM	*P*-value	
	CON	LATE42	LATE84		Treatment	Treatment × day
Steer feedlot BW[3], kg						
Arrival	249	247	260	7.3	0.36	0.72
Feedlot entry	247	242	258			
End of growing phase	399	394	410			
Feedlot exit	564	558	566			
Steer feedlot ADG[3], kg/d						
Receiving phase	−0.11	−0.34	−0.12	0.14	0.49	
Growing phase	1.60	1.61	1.63	0.04	0.37	
Finishing phase	1.50	1.45	1.38	0.04	0.43	
Feedlot entry to exit	1.54	1.53	1.50	0.03	0.92	
Arrival to feedlot exit	1.44	1.40	1.39	0.03	0.54	
Steer feedlot DMI[3], kg/d						
Growing phase	7.04	7.32	7.32	0.19	0.51	
Finishing phase	9.04	9.53	9.24	0.24	0.37	
Total	8.12	8.41	8.35	0.20	0.57	
Steer feedlot G:F[3]						
Growing phase	0.21	0.21	0.21	0.005	0.89	
Finishing phase	0.17[b]	0.15[a]	0.15[a]	0.005	0.06	
Total	0.18[b]	0.17[a]	0.17[a]	0.003	0.09	

[1]Treatments consisted of: CON, no maternal prepartum supplementation with DDG from day 0 to 84; LATE42, maternal supplementation of 2 kg/d of DDG from day 0 to 42; and LATE84, maternal supplementation of 1 kg/d of DDG from day 0 to 84.
[2]Steers arrived at Butner Beef Cattle Laboratory, North Carolina State University, on day 348 and were kept on pasture 14 d after arrival. All steers entered the feedlot on day 361. The growing diet was fed for 104 and 86 d in year 1 and 2, respectively. The finishing diet was fed for 111 and 95 d in year 1 and 2, respectively.
[3]ADG, average daily gain; BW, body weight; G:F, gain:feed.
[a,b]Within a row, means without common superscript differ ($P \leq 0.05$).

Table 11. Carcass characteristics of steers born to *Bos indicus*-influenced beef cows offered no prepartum supplementation (CON) or dried distillers grains (DDG) supplementation during the first half (LATE42) or entire third trimester of gestation (LATE84; 2 pastures/treatment/yr)

Item	Maternal treatment[1]			SEM	*P*-value
	CON	LATE42	LATE84		Treatment
Hot carcass weight, kg	337	338	338	5.5	0.98
Dressing percent[2], %	59.7	60.5	59.8	0.30	0.12
12th Rib fat thickness, cm	1.77	1.69	1.62	0.089	0.49
Longissimus muscle area, cm2	79.2	80.8	80.7	1.58	0.74
KPH, %	2.92	2.62	2.67	0.13	0.20
Yield grade	3.8	3.6	3.5	0.14	0.33
Marbling[3]	521[a]	570[b]	545[a,b]	15	0.07
Average choice, %	5[a]	36[b]	17[a,b]	9.3	0.10
Low choice, %	72	46	58	10	0.17
Select, %	23	19	25	8	0.87

[1]Treatments consisted of: CON, no maternal prepartum supplementation with DDG from day 0 to 84; LATE42, maternal supplementation of 2 kg/d of DDG from day 0 to 42; and LATE84, maternal supplementation of 1 kg/d of DDG from day 0 to 84.
[2]Dressing percent calculated from dividing the unshrunk final body weight by the hot carcass weight.
[3]500 = small[0].
[a,b]Within a row, means without common superscript differ ($P \leq 0.05$).

adequate BCS of 6 during the same period (Marques et al., 2016). However, the present experiment provided evidence that a more consistent supply of nutrients during the last trimester of gestation (LATE84) optimized calf preweaning growth. In support of this rationale, the BCS change of LATE42 cows was greater compared with LATE84 cows, suggesting that nutrients were potentially diverted away from the fetus and were deposited as fat reserves. Alterations to maternal diet during gestation can influence visceral organ mass (Meyer et al., 2010) and the expression of genes related

to muscle development (Paradis et al., 2017; Liu et al., 2020; Palmer et al., 2021a). It is plausible that a more consistent delivery of nutrients during the third trimester of gestation in LATE84 calves had a greater impact on in utero programming of offspring postnatal growth compared with LATE42 calves. To our knowledge, this is the first study that has investigated the effects of a protein and energy supplement during only the first half of the third trimester of gestation. Further studies exploring the underlying molecular and physiological mechanisms programmed by different timing of maternal DDG supplementation during gestation are warranted.

Postweaning (day 347 to slaughter)

Prenatal exposure to stress can modify the hypothalamic–pituitary–adrenal (**HPA**) axis and alter circulating cortisol concentrations in the offspring (Lay et al., 1997; Littlejohn et al., 2016). Nutrient restriction (57% vs. 100% of nutrient requirements) during the last 90 d of gestation increased circulating cortisol concentrations of calves at birth (Hough et al., 1990). Furthermore, calves born to *B. taurus* cows offered 70% of their energy requirements during the last 40 d of gestation had reduced concentration of cortisol following a postweaning vaccination challenge compared with calves born to cows offered 100% of their energy requirements (Moriel et al., 2016). In the present study, plasma cortisol concentrations were not impacted by maternal treatments. These results corroborate previous findings from our research group in *B indicus*-influenced calves. Moriel et al. (2020) reported that protein and energy supplementation during the last 57 d of gestation did not impact plasma cortisol concentrations of early-weaned beef calves following a vaccine-induced immunological challenge. A direct comparison of breeds within the same study is warranted, but it remains plausible that breed could partially explain the discrepancy on impacts of maternal gestational diet on offspring HPA activity (Moriel et al., 2021).

Haptoglobin is an acute-phase protein whose production is induced by inflammatory cytokines (Gabay and Kushner, 1999). Following an immune challenge, genes (*IL1B* and *NFKB1*) associated with the inflammatory response were upregulated in dairy calves born to cows that calved in a greater BCS (Lopes et al., 2021). However, greater prepartum energy intake reduced circulating haptoglobin concentrations in dairy calves at 7 d of age (Osorio et al., 2013) and had no effect on circulating haptoglobin concentrations in beef calves at birth (Moriel et al., 2016). Plasma haptoglobin concentrations following weaning and arrival at the feedlot were not impacted by maternal supplementation of DDG, regardless of supplementation length. Similarly, Moriel et al. (2020) observed that prepartum supplementation of protein and energy did not affect plasma haptoglobin concentrations following vaccination. Collectively, the observed results for plasma cortisol and haptoglobin concentrations suggest that maternal supplementation of protein and energy during the third trimester of gestation did not impact postnatal innate immune response to vaccination in *B. indicus*-influenced beef calves.

Maternal energy status during the second and third trimesters of gestation programmed the postnatal humoral immune response of the offspring (Taylor et al., 2016; Moriel et al., 2016, 2020). The present study found that steers born to LATE42 and LATE84 cows had increased serum PI_3 titers and greater seroconversion at weaning compared with steers born to CON cows. The increase in positive seroconversion of LATE42 and LATE84 steers at weaning indicates that a short-term nutrient-restriction during the third trimester of gestation experienced by CON cows suppressed calf post-vaccination humoral immune function, which corroborates with Moriel et al. (2016). Following vaccination at the time of weaning, the percentage of steers with positive seroconversion for PI_3 at 42 d after feedlot arrival did not differ among treatments. It is possible that supplementation of protein and energy during the third trimester of gestation, regardless of supplementation length, leads to a more responsive or an earlier development of the humoral immune function in beef calves. Moriel et al. (2020) also reported a greater percentage of calves with positive seroconversion against BVDV-1 and PI_3 viruses when cows were offered a protein and energy supplement during the third trimester of gestation. Improvements to the calf humoral immune response could potentially explain the reduction in respiratory disease incidence at feedlot entry when steers were born to cows supplemented with protein during late gestation compared with no prepartum supplementation (Larson et al., 2009).

In the present study, steer feedlot BW, ADG, and DMI did not differ among maternal treatments. Although, CON steers tended to have a greater G:F ratio compared with LATE42 or LATE84 steers. The impact of maternal nutrition during gestation on subsequent feedlot performance has been inconsistent and less studies continue to evaluate the impact of maternal gestational nutrition on calf postweaning performance as compared with calf preweaning performance (Moriel et al., 2021). Several studies have reported that prepartum supplementation during the last trimester of gestation did not increase feedlot ADG or DMI (Stalker et al., 2006; Bohnert et al., 2013; Shoup et al., 2015b; Summers et al., 2015a; Wilson et al., 2015). Contrastingly, steers born to cows supplemented with 0.45 kg/d of a protein (28% or 42% CP) supplement during the entire length of late gestation had greater final feedlot BW and ADG compared with steers born to cows that received no prepartum supplementation (Stalker et al., 2007; Larson et al., 2009). Discrepancies between studies could be attributed to the amount of supplement provided, duration of supplementation, supplement type and source, cow age and breed, calf postnatal nutrition, and the interaction between prenatal and postnatal nutrition (Moriel et al., 2021).

HCW was not impacted by maternal treatment. In agreement, maternal supplementation with DDG during late gestation did not impact steer HCW compared with no prepartum supplementation (Bohnert et al., 2013; Wilson et al., 2015). In the present study, maternal treatment did not affect other carcass variables including LMA, 12th-rib fat thickness, KPH, dressing percent, and yield grade, corroborating with Bohnert et al. (2013). Interestingly, marbling scores increased in LATE42 vs. CON steers, resulting in a greater percentage of LATE42 carcasses grading average choice compared with CON carcasses. Thus, concentrating DDG supplementation during the first half of late gestation had greater impacts on carcass quality at slaughter in comparison to offering no prepartum supplementation. Marbling did not differ between steers on the LATE84 and CON treatments. This was surprising considering that protein supplementation during the entire third trimester of gestation increased marbling scores of steers compared to no prepartum supplementation (Larson et al., 2009).

Late gestation is a critical window of muscle development and the initiation of adipogenesis (Du et al., 2010). Muscle

and adipose tissue are both derived from mesenchymal stems cells during fetal development; thus, the differentiation to muscle or adipose tissue is considered a competitive process that is ultimately influenced by numerous factors (Du et al., 2011; Yan et al., 2013). Both CCAAT/enhancer-binding proteins (**C/EBPs**) and peroxisome proliferator-activated receptor (**PPAR**) γ are critical transcription factors regulating the differentiation of stem cells to an adipogenic lineage (Brun et al., 1996; Darlington et al., 1998). Overnutrition during gestation in *B. indicus* cows increased the expression of *C/EBPα* and *PPARγ* in fetal muscle tissue (Duarte et al., 2014). It is plausible that concentrating supplementation during the first half of the third trimester of gestation, when the energy requirements of pregnant cows are the least, altered nutrient partitioning and increased proliferation and differentiation of adipose cells rather than muscle fibers. Overall, these results suggest that concentrating protein and energy supplementation to the first half of the third trimester of gestation could be a management strategy to improve the marbling and carcass quality of the beef offspring.

Conclusions

Prepartum supplementation of DDG, regardless of supplementation length, increased cow BCS at calving compared with cows that received no prepartum supplementation. However, concentrating DDG supplementation to the first half of the third trimester of gestation resulted in cows calving their second offspring earlier in the subsequent calving season. Prepartum DDG supplementation did not alter the birth weights of the first offspring but increased offspring weaning weights compared with no prepartum supplementation. However, the weaning weights of the first offspring increased to the greatest extent when cows were offered a consistent supply of DDG during the entire third trimester of gestation. Steer antibody response to PI_3 following vaccination was enhanced when cows were offered prepartum DDG supplementation, regardless of supplementation length, compared with no prepartum supplementation. Lastly, concentrating DDG supplementation in the first half of the third trimester of gestation improved marbling and quality grade of carcasses compared with no prepartum supplementation or DDG supplementation for the entire third trimester of gestation. To our knowledge, this is the first study to demonstrate that the timing of a protein and energy supplement during the last trimester of gestation impacts different aspects of offspring productive responses, providing potential explanations for the inconsistent results on maternal gestational diet-induced offspring performance. Overall, different timing of protein and energy supplementation during the third trimester of gestation could be explored to increase cow BCS at calving and offspring preweaning growth, postweaning immune function, and carcass quality.

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Conflict of interest statement

The authors declare no real or perceived conflicts of interest.

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