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Supplementary strategies for beef cows during the peripartum period in tropical conditions

Johnnatan Castro Cabral Gonçalves

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À Deus, que nos proporciona esperança e força em cada etapa da vida.

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“Sua cabeça é sua guia”.

ABSTRACT

GONÇALVES, Johnnatan Castro Cabral, M.Sc., Universidade Federal de Viçosa, February, 2025. **Supplementary strategies for beef cows during the peripartum period in tropical conditions**. Adviser: Sidnei Antonio Lopes.

The objective of this study was to evaluate how different supplementation strategies affect the performance and reproduction of beef cows and their offspring. In Chapter 1, forty multiparous Nellore cows (533 ± 32 kg; body condition score 5.7 ± 0.4) were supplemented with either a mineral mixture or protein-energy supplements (1 kg/animal/day, as-fed basis) containing different levels of dried distillers grains (DDG – 0%, 42%, or 84%) during the last third of gestation. A quadratic effect of supplementation on body weight variation before and after calving was observed ($P<0.05$), with cows fed 42% DDG gaining more weight prepartum, and cows in the 0% DDG group losing more weight postpartum. Cows supplemented with 0% or 42% DDG had lower concentrations of non-esterified fatty acids and ß-hydroxybutyrate before calving ($P<0.05$). However, average measures such as body weight, body condition score, carcass traits, and metabolic indicators varied only according to the day of measurement ($P<0.05$). Maternal supplementation did not influence fetal development, offspring metabolic profile, maternal milk yield, or postnatal performance of the calves ($P>0.05$). In Chapter 2, a meta-analytical approach was used to assess different supplementation strategies for multiparous Nelore cows from late gestation—no supplementation, prepartum, postpartum, or both—on the productive and reproductive performance of the cow-calf pair in tropical conditions. Calf supplementation through a creep-feeding system was also evaluated. Prepartum supplementation improved prepartum weight gain, body condition score, and cow body weight at calving ($P<0.10$). Cows supplemented only before calving lost more weight postpartum compared to other treatments ($P<0.10$). Postpartum-only supplementation increased the pregnancy rate at first insemination ($P<0.10$), but treatment did not affect conception after two inseminations ($P>0.10$). Maternal supplementation did not influence calf birth or weaning weight ($P>0.10$), while creep-feeding improved calf performance during the suckling phase ($P<0.10$). When included up to 42% in supplements, DDG enhances the productive and metabolic performance of beef cows during late gestation on low-quality pastures. Postpartum-only supplementation increases early breeding season pregnancy rates. Peripartum maternal supplementation does not affect offspring performance, while creep-feeding improves pre weaning calf performance. Combined, these strategies support technical decisions aimed at sustainably optimizing productivity in beef cattle systems.

Keywords: negative energy balance; late gestation; nellore; creep-feeding

RESUMO

GONÇALVES, Johnnatan Castro Cabral, M.Sc., Universidade Federal de Viçosa, fevereiro de 2025. **Estratégias suplementares para vacas de corte durante o periparto em condições tropicais**. Orientador: Sidnei Antonio Lopes.

O objetivo deste estudo foi avaliar como diferentes estratégias suplementares afetam a performance e reprodução de vacas de corte e suas crias. No Capítulo 1, 40 vacas Nelore multíparas com 533 ± 32 kg e 5,7 ± 0,4 pontos de escore de condição corporal, foram suplementadas com mistura mineral ou suplementos proteico-energéticos (1 kg/animal/dia, base na matéria natural), contendo diferentes inclusões de grãos secos de destilaria (DDG - 0%, 42% ou 84%) durante o terço final da gestação. Houve efeito quadrático da suplementação sobre a variação do peso corporal no pré e pós-parto (P<0,05), com vacas tratadas com 0% e 42% de DDG apresentando maior ganho de peso no pré-parto, e vacas do grupo 0% DDG apresentando maior perda de peso no pós-parto. Vacas suplementadas com 0% ou 42% de DDG apresentaram menores níveis de ácidos graxos não esterificados e ß-hidroxibutirato no pré-parto (P<0,05). Apesar disso, médias pontuais de peso, como escore de condição corporal, características de carcaça e indicadores metabólicos variaram apenas conforme o dia de mensuração (P<0,05). Não houve influência da suplementação das vacas sobre o desenvolvimento fetal, perfil metabólico da prole, produção de leite materno ou desempenho pós-natal da prole (P>0,05). No Capítulo 2, foi utilizada uma abordagem meta-analítica para avaliar diferentes estratégias suplementares de vacas Nelore multiparas a partir do terço final da gestação – ausência de suplementação, suplementação no pré-parto, no pós-parto ou em ambos os períodos – sobre o desempenho produtivo e reprodutivo do par vaca-bezerro em condições tropicais. Também foi avaliada a suplementação de bezerros em sistema de creep-feeding. Vacas suplementadas no pré-parto apresentaram maior ganho de peso e escore de condição corporal no pré-parto, além de parirem mais pesadas (P<0,10). Vacas suplementadas no pré, mas não no pós-parto, perderam mais peso em comparação aos demais tratamentos (P<0,10). A suplementação exclusiva no pós-parto aumentou a taxa de prenhez na primeira inseminação (P<0,10), mas o tratamento não afetou a concepção após duas inseminações (P>0,10). A suplementação materna não afetou o peso da prole, tanto ao nascimento quanto na desmama (P>0,10), enquanto a estratégia de creep-feeding demonstrou ser eficaz para melhorar o desempenho dos bezerros na fase de cria (P<0,10). Quando incluído até o nível de 42% em suplementos, o

DDG melhora a performance produtiva e metabólica de vacas de corte durante o terço final da gestação em pastos de baixa qualidade. A suplementação exclusiva pós-parto se aumenta a taxa de prenhez no início da estação de monta. A suplementação materna no periparto não afeta o desempenho da prole. Por outro lado, a estratégia creep-feeding é capaz de melhorar o desempenho desses animais no pré-desmame. Quando combinadas, essas estratégias embasam decisões técnicas para otimizar a produtividade de forma sustentável na cria de bovinos de corte.

Palavras-chave: balanço energético negativo; terço final da gestação; nelore ; creep-feeding

SUMMARY

CHAPTER 1 - EFFECTS OF DRY DISTILLER'S GRAINS IN SUPPLEMENTS FOR BEEF COWS DURING LATE GESTATION ON THE COW-CALF PAIR IN LOW-QUALITY PASTURE

Abstract

Forty multiparous Nellore cows, with an average body weight, body condition score, and gestation days of 533 ± 32 kg, 5.7 ± 0.4 points, and 198 days, respectively, received or did not receive 1 kg/day of supplement with varying inclusion levels of dried distillers' grains (DDG) (Control, 0%DDG, 42%DDG, or 84%DDG) in the last third of gestation. The objectives were to evaluate the effects of prepartum DDG supplementation on performance, reproduction, fetal development, and calf performance. A quadratic effect of supplementation on BW variation pre- and postpartum was observed ($P<0.05$), with cows treated with 42% DDG showing higher BW gain prepartum, and 0% DDG higher BW loss postpartum. Cows supplemented with 42% DDG had lower levels of non-esterified fatty acids and β-hydroxybutyrate prepartum ($P<0.05$). However, body weight-related metrics, such as condition score, carcass traits, and metabolic indicators, varied only by measurement day ($P<0.05$). No effect of supplementation was observed on fetal development, calf metabolic profile, milk yield, or postnatal calf performance ($P>0.05$). It is recommended to include up to 42% DDG in supplements for beef cows during late gestation grazing on low-quality tropical forage conditions.

Keywords: metabolizable protein, ethanol byproduct, negative energy balance.

Introduction

The negative energy balance is inevitable during the peripartum period, as the homeorhetic adaptations are necessary to support fetal development and initial milk production (BAUMAN & CURRIE, 1980; WOOD et al., 2013; CONTRERAS et al., 2017). This condition can be exacerbated in tropical beef cattle production due to the reduction in voluntary intake near calving (DAVID et al., 2024) and the nutritional constraints associated with the seasonal variation in forage quality (PAULINO et al., 2014).

Improving the nutritional status of beef cows during the prepartum period to ensure an adequate body condition score (BCS) at calving can benefit cow-calf systems by reducing the calving interval, shortening the postpartum anestrus period, enhancing conception rates, and promoting fetal development (BOHNERT et al., 2013; LEMASTER et al., 2017; CARVALHO et al., 2022; CHEN et al., 2022). Under tropical conditions, strategic supplementation programs can be effectively implemented during the last trimester of gestation to ensure adequate BCS at calving, even when forage resources are of low nutritional value (ALMEIDA et al., 2020; MORENO et al., 2023; SARAIVA et al., 2024). This approach is viable because the final trimester of gestation typically coincides with weaning, a phase when maternal nutrients requirements are relatively lower due to the reduction in lactation demands (GIONBELLI et al., 2023; LOPES et al., 2023).

The inclusion of coproducts from sucroenergetic industry in animal nutrition can be considered sustainable from social, environmental, and economic perspectives (GARCÍA-FRANCO et al., 2021). Among these coproducts, dry distillers' grains (DDG) are particularly valuable for their nutritional profile, characterized by a high concentration of rumen undegradable protein (RUP), digestible fiber, and low-fat content (LIU, 2011; VALADARES FILHO et al., 2023). Thus, they can be a direct source of metabolizable protein and fermentable compounds. However, the primary demand of rumen microorganisms for nitrogen compounds raises questions about the efficiency of RUP in supplements designed for beef cattle grazing on low-quality forages. A certain amount of latent energy can be extracted from low-quality fibrous compounds when the nitrogen requirements of rumen microorganisms are met (DETMANN et al., 2024). On the other hand, when the ruminal nitrogen demand is not met, recycling events reduces the efficiency of metabolizable protein utilization (DETMANN et al., 2014).

The effects of RUP supplementation combined with non-starch carbohydrates, like offered by DDG, under low-quality forage conditions remain poorly understood, particularly for cows in the last trimester of gestation. For overfed beef cows, the potential benefits of such supplementation include improved prepartum performance, enhanced protein metabolic status, and increased adipogenic and myogenic potential in the offspring (COSTA et al., 2022). For steers grazing low-quality pasture, the consumption of distillers' grains improved ruminal metabolism (MURILLO et al., 2016), while for cows in a nutritionally restricted state, distillers' grains supplementation may improve performance and body condition from calving to the breeding season (WILSON et al., 2015). Additionally, when economically feasible, replacing conventional true protein sources with DDG and adjusting the supply of rumen degradable protein (RDP) with urea can be an effective strategy for finishing systems under conditions of low-quality forage availability (HOFFMANN et al., 2021).

We hypothesize that the inclusion of DDG in low-consumption protein-energy supplements offered during late gestation enhances the metabolic status, reproductive and productive performance of beef cows, as well as the performance and metabolic efficiency of their offspring. The objective of this study was to evaluate the effects of the inclusion of DDG in low consumption supplements on the performance, reproductive, and metabolic parameters of beef cows and their progeny.

Materials and Methods

The experiment was conducted between June and November 2022 at the Beef Cattle Teaching, Research, and Extension Unit of the Federal University of Viçosa, Minas Gerais, Brazil. All procedures involving animals were previously approved by the Animal Use Ethics Committee of the Federal University of Viçosa (protocol number 11/2022).

Animals, Experimental Design, and Treatments

Forty multiparous Nellore cows at 198 days of gestation (inseminated at the same day) with body weight (BW) of 533 ± 32 kg and BCS 5.7 ± 0.4, were randomly allocated into eight pastures of *Urochloa decumbens* (2.7 ha and 5 cows/pasture). Pastures were equipped with covered feeders and water troughs.

Each group of five animals was formed randomly and treatments were randomly assigned to the groups and consisted of: control - animals receiving mineral mixture *ad libitum* and supplemented - with supplements containing different levels of DDG: 0% DDG, 42% DDG, or 84% DDG (Table 1). The supplements were formulated to contain 40% crude protein (CP) on a dry matter (DM) basis and were offered daily at a rate of 1 kg/animal to meet about 35% of the requirements for CP (GIONBELLI et al., 2023). The supplement was provided on average for 85 days prior to calving, always at 11:00 a.m. After calving, the groups were maintained and received mineral mixture *ad libitum*.

Productive performance

The cows were weighed on d-90, d-60, d-30, d-1, d1, d30, and d60 relative to calving (d0). The calves were weighed on days d1 and d60 after birth. On d-90, d-1, and d60, BCS, scale of 1 to 9 (NRC, 2000), was assessed by five trained evaluators, and carcass ultrasonography was performed. Images of the *Longissimus dorsi,* taken between the 12th and 13th ribs, and the intersection of the *Gluteus medius* with the *Biceps femoris*, were captured using an ultrasound device (SSD 500V®, Aloka) equipped with an 18 cm linear probe. The ribeye area (RBA) and subcutaneous fat thickness at the rump (rFT) were measured using the BioSoft Toolbox® II for Beef software (Biotronics Inc.).

The variation in productive performance measurements (BW, BCS, RBA and rFT) in cows was calculated by the relationship between the measurement at calving and the initial measurement during the prepartum period, or between the final measurement and calving, based on the measurement at calving, when designated as postpartum.

To estimate milk production, cows were milked in the 3rd and 5th weeks after calving. Milking procedures were performed with controlled suckling period prior to calf separation. Cows were milked at 5 a.m. after being separated from their calves for twelve hours, followed by the administration of 1 mL of oxytocin (10 IU/mL, Ocitopec®, Biovet). Daily milk yield and the above-mentioned procedures were based on the morning milk yield adjusted to 24 hours (LOPES et al., 2022).

Estimation of forage and supplement availability and quality

Every 14 and 28 days, forage samples were collected to evaluate the quality and mass availability, using the hand-plucking technique and the square technique, respectively. The samples for evaluating forage mass were collected by cutting at ground level in four representative areas of each paddock, delimited to 0.25 m², to quantify DM offer and potential digestible dry matter (pdDM) offer. The samples were weighed, oven-dried (55 °C), and then processed in Willey-type mills, using 1 mm and 2 mm screens. The pdDM (Equation 1) was estimated considering the animal stocking rate, the period between collections, and the forage availability per hectare (PAULINO et al., 2008).

$$\boldsymbol{pdDM = 0.98 * (100 - NDF) + (NDF - iNDF)} \quad \text{eq.1}$$

where: pdDM = forage content of potentially digestible DM; 0.98 = true digestible coefficient of cell content; and NDF and iNDF = forage content of NDF and iNDF, respectively.

Forage and supplement samples were analyzed according to the standard analytical procedures of the Instituto Nacional de Ciência e Tecnologia – Ciência animal (INCT, CA) (DETMANN et al., 2021). The methods used were: dry matter content (DM, INCT-CA method G-003/1), mineral matter (MM, INCT-CA method M-001/2), CP (CP, INCT-CA method N-001/2), neutral detergent fiber corrected for ash and protein (apNDF, INCT-CA method F-013/1), neutral detergent insoluble protein (NDIP, INCT-CA method N-004/2), neutral detergent insoluble ash (NDIA, INCT-CA method M-002/2), and indigestible neutral detergent fiber, determined by in situ incubation in non-woven fabric bags (100 g/m^2) for 288 hours, with samples processed through a 2 mm sieve (iNDF, INCT-CA method F-009/2). The RDP and RUP concentrations of the supplements were estimated based on tabulated values (VALADARES FILHO et al., 2023).

Blood and Skeletal Muscle Collection: Processing and Analysis

Blood samples were collected from the jugular vein, prior to supplementation, in vacuum tubes with a separator gel and clot accelerator, on d-30, d-15, d1, d15, d30, d45, d51, and d60. Calf blood was collected on d1 and d15 relative to birth. After collecting, the samples were centrifuged at 2500 x g for 15 minutes to obtain blood serum. Serum was frozen at -20°C in microtubes for subsequent analyses. Cow and calf serum were analyzed for the concentrations of total protein (K031, Biuret Method, Bioclin), albumin (K040, Bromocresol Green Method, Bioclin), glucose (K082, Enzymatic Colorimetric Method, Bioclin). Additionally, cow's serum was analyzed for urea (K056, UV kinetic method, Bioclin) and total cholesterol (K083, Enzymatic Colorimetric Method, Bioclin). Non-esterified fatty acids (NEFA) and β-hydroxybutyrate (βHB) were evaluated in cows' serum using Randox kits (FA115, Colorimetric Method and RB1007, Enzymatic Method, respectively). All above mentioned analyses were performed at the Animal Physiology Laboratory of the Department of Animal Science at the Federal University of Viçosa using an automated biochemical analyzer (Mindray, BS200E). Insulin-like growth factor type 1 (IGF-1) was quantified on d-30, d-15, d1, d15, d30, d51 for cows and on d1 for calves using DiaSorin kits, in an automated chemiluminescence analyzer (LIAISON XL, DiaSorin). Cows' and Calves' globulin concentrations were calculated by the difference between total protein and albumin. Serum urea nitrogen was estimated to be 46,67% of urea.

Longissimus dorsi muscle samples, located between the 10th and 11th ribs, were collected by biopsy from the offspring at 55 days of age. The procedure was carried out with the appropriate veterinary care, including the application of local anesthesia (Lidocaine 2%, LidoVet, Bravet) and suturing after collection. The animals were monitored and treated with antibiotics and anti-inflammatory drugs, and the sutures were removed two weeks later. Approximately 1 cm^3 of muscle was collected and fixed in 10% formalin for histological analysis. The samples were dehydrated using a growing ethanol series (70% to 100%), followed by embedding in xylene and, subsequently, in liquid paraffin for block preparation. Sections of 5 µm were obtained using a rotary microtome and stained with hematoxylin-eosin. The slides were mounted in Entellan® and prepared for analysis. To observe muscle cell area, digital images of the muscle sections per animal were obtained using an EvosFL microscope (ThermoScientific) and analyzed using ImageJ software (National Institute of Health). To obtain the average muscle fiber area for each sample, measurements were made in 30 different cells in different regions of the slide containing the muscle tissue sample.

Measures and Reproductive Protocol

The breeding season started at 61 ± 5 days after calving and involved two artificial inseminations. Cows were synchronized using the following protocol: on day -10 relative to insemination, a slow-release progesterone intravaginal device (Tecnopec Primer) was inserted, and an intramuscular injection of 2.0 mg of estradiol benzoate (Tecnopec RIC-BE) was administered. On day -2, the intravaginal device was removed, and the cows received an intramuscular injection of 0.48 mg of sodium cloprostenol (Tecnopec Estron), 300 IU of equine chorionic gonadotropin (Zoetis-Pfizer Novormon), and 1 mg of estradiol cypionate (Zoetis-Pfizer E.C.P.). Timed artificial insemination (TAI) was performed 46–52 hours after the removal of the intravaginal device on the insemination day. Semen from five Nellore bulls were randomly assigned to each cow. The protocol was repeated 14 days after the insemination in the same manner. On day 22, the implant was removed, and pregnancy diagnosis was performed by color Doppler ultrasound (Mindray, DP 50). Non-pregnant cows received an intramuscular injection of 0.48 mg of sodium cloprostenol (Tecnopec Estron), 300 IU of equine chorionic gonadotropin (Zoetis-Pfizer Novormon), and 1 mg of estradiol cypionate (Zoetis-Pfizer E.C.P.). TAI was performed again 46–52 hours after the removal of the intravaginal device on day 24. A new pregnancy diagnosis was conducted 30 days later, confirming pregnancies from both the first and second inseminations. The pre-ovulatory follicle diameter (POFD) at the first insemination was measured as reproductive success. Due to the number of animals, conception rates were not statistically analyzed.

Statistical Analysis

The experiment was conducted using a randomized design. Response variables related to productive performance and the metabolic profile of cows over time were analyzed using the GLIMMIX (SAS Institute Inc.) for repeated measures data. The MIXED procedure of SAS was used to analyze response variables related to the calves and variations in productive performance measures (relative changes in pre- and postpartum BW, BCS, RBA and rFT), for milk production and POFD.

The models included fixed effects of treatment, day and their respective interactions, while treatment nested with group was declared as random effect. For variables measured in the calves, the effect of sex was controlled. The effect of the group nested within each treatment was considered a random effect. For all variables, means were compared with adjustments for multiple comparisons, and contrasts were applied to evaluate specific comparisons between treatments and interactions, including the supplementation effect (Sup) and linear (L) and quadratic (Q) trends among treatments. A significance level of 5% was considered the critical value for type I error.

Results

The forage DM allowance during pre- and post-partum periods was 71.6 and 67.6 g/kg of BW, respectively, corresponding to an average pdDM allowance of 44.6 g/kg BW. During these periods, the CP content of the pasture was 4.0% and 8.1%, while the average concentration of apNDF in the forage was 74.3% and 67.3% (Table 2).

A quadratic effect of DDG levels was detected on BW variation ($P=0.047$) (Table 3), where 42% DDG had greater weight gain in the prepartum and cows in 0% DDG had greater BW loss in postpartum. However, treatment did not affect the relative variation of BCS, RBA and rFT ($P>0.05$) (Table 3), just showing a positive overall variation in the prepartum and a negative variation in the postpartum period ($P<0.05$).

No treatment effects and interactions with measurement day were observed on BW, BCS, RBA and rFT spot measurements ($P>0.05$) (Figure 1). The BW increased between d-90 and d-60 ($P<0.001$), remaining stable until d-1 ($P=0.09$). In the postpartum period, there was a significant BW reduction between d1 and d30 ($P<0.001$). The BCS, RBA and rFT were similar between the beginning of the experiment and parturition ($P>0.05$) but were lower on d60

(P<0.05). Regarding milk production and reproduction, there was no effect of treatment on milk production (P=0.75), being the average 7.4 kg/day and treatment did not affect POFD (P=0.68), which averaged 16.2 mm. The average conception rate on the first AI was 79,9% and just one cow of 84% DDG did not conceive after two AI.

Supplementation increased the SUN concentration in prepartum period (P=0.020; Table 4). An interaction was observed (P<0.001), with SUN concentrations being higher in supplemented cows on d-30 and higher in the 0% DDG treatment, intermediate in 42% DDG and 84% DDG, and lowest in control treatment on d-15. An interaction between treatment and collection day was observed for total cholesterol (P=0.036), BHB (P=0.033), and NEFA (P=0.012) (Table 4).

Concentration of total cholesterol was lower only for 0% DDG compared to 84% DDG on d1 (P=0.046). On d30, the concentration was higher in the control group compared to 84% DDG (P=0.018). The lowest concentration of BHB on d-30 was observed for the 42% DDG treatment compared to the 84% DDG treatment (P=0.039) and on d-15 compared to the Control treatment (P=0.007). Supplementation affected the NEFA concentration (P=0.049), being higher for the Control treatment during the prepartum period, but the contrasts revealed similarity with 84% DDG d-30 (P=0.46) and d-15 (P=0.11). The NEFA concentration in Control cows was also higher on the day after calving but only differed from the 84% DDG treatment (P=0.020).

The concentrations of IGF-1, glucose, total proteins, albumin, and globulin were not affected by treatment (P>0.05) but varied according to collection day (P<0.001; Figure 2). Glucose levels were greatest on d1, followed by d45 and were lowest on d60 (P<0.05). IGF-1 levels decreased from d-30 to d15, then increased from d15 to d30 (P<0.05). Total proteins and albumin concentrations decreased from d-30 to d30, then increased from d30 to d45 (P<0.05). Globulins decreased from d-30 to d-15 and remained at a constant level until d30, when they increased between d30 and d45 (P<0.05).

The effect of sex was controlled in the variables measured in the calves and did not interfere with the results. No treatment effect was observed for weight or average daily gain of calves up to 60 days, nor an interaction between treatment and day for BW (P>0.05) (Table 5). The average cross-sectional area of muscle fibers in the Longissimus dorsi muscle was 680.8 μm^2 and did not differ between treatments (P=0.60). The IGF-1 concentrations on d1 were not different according to treatment, nor were the concentrations of total proteins, albumin, and globulins (P>0.05), which only varied according to the day of collection (P<0.05). In overall, total protein and globulin levels decreased over time, while albumin concentrations increased from d1 to d15 (Table 5). Glucose concentrations did not vary between treatments (P=0.78) or between measurement days (P=0.38) (Table 5).

Discussion

Although supplementation may alleviate negative energy balance and reduce the mobilization of reserves to meet the gestational component at late gestation, we did not observe differences between treatments in body condition measures assessed by BCS and carcass ultrasound. Studies under similar conditions also found no impact of low-intake protein-energy supplementation (around 2 g/kg BW) on performance (FERREIRA et al., 2020; SARAIVA et al., 2024). However, this strategy may be effective for smaller-framed cows and those with lower condition score, typically classified as below 5 BCS, due to their lower nutritional requirements (ALMEIDA et al., 2020; GIONBELLI et al., 2023; MORIEL et al., 2024).

Although we did not observe an overall effect of supplementation on BW and condition scores, we detected a quadratic effect on BW variation. Cows supplemented with 42% DDG showed higher relative weight gain during the final third of gestation, while those supplemented with 84% DDG had lower gains, similar to the Control. This effect was supported by reduced levels of NEFA and BHB in prepartum cows supplemented with 42% DDG, indicating less mobilization of body reserves. Since these metabolites are directly associated with energy deficit and mobilization of reserves (DIAZ-GONZALEZ; SILVA, 2017), our results suggest that supplementation above 42% DDG is not effective in alleviating the negative energy balance in pregnant beef cows under tropical conditions, which is necessary to maintain the gestational component during the final third of gestation.

Both the availability of body reserves and nutritional intake during the final third of gestation are crucial for fetal development (BOHNERT et al., 2013; CHEN et al., 2022; LEMASTER et al., 2017). During this period, cows adjust their nutritional requirements to allocate more nutrients to the gestational component (WOOD et al., 2013; ROTTA et al., 2015; GIONBELLI et al., 2023). When cows have adequate body reserves, they can compensate for the adverse effects of mild nutrient deficiencies, resulting in loss of maternal tissue. Thus, it is likely that the cows receiving 42% DDG allocated a greater amount of nutrients to the gestational component. However, the cows were generally in good body condition, and therefore, the controlled mobilization of their reserves was sufficient to mitigate the potential negative effects of maternal nutritional restriction on the fetus. This was evidenced by the offspring's birth weight and muscle fiber size, which did not differ between treatments.

A minimum ruminal ammonia nitrogen is necessary to ensure optimal energy extraction from low-quality fibrous components by fibrolytic microorganisms (DETMANN et al., 2014). Nitrogen supplementation, combined with rapidly fermentable carbohydrates, also promotes the availability of metabolizable compounds such as volatile fatty acids and microbial protein (FRANCO et al., 2016). Corn processing increases the levels of RUP, while most non-fibrous carbohydrates are fermented to ethanol, concentrating the fibrous fraction in DDG (LIU, 2011). Although this fraction is degradable, its degradation rate is slower compared to soluble carbohydrates.

In our study, DDG supplements showed a gradual increase in fiber and indigestible fiber levels, along with a decrease in degradable protein in the rumen (Table 1). This behavior is associated with lower nitrogen availability in the rumen, which was reflected in the lower NUS concentrations between supplemented cows (Table 4). Therefore, the synchrony between soluble nitrogen and rapidly fermentable carbohydrates, along with an intermediate amount of RUP, may have benefited animals in the 42% DDG treatment. Although studies on ruminal metabolism in pregnant cows grazing low-quality pastures are scarce, this is supported by data from Picanço et al. (2024), which indicate that DDG inclusion levels above 20% in supplements result in decreased forage intake, dry matter digestibility, and fibrous fraction digestibility. Data from Detmann et al. (2024) also reinforces that the digestibility of the fibrous fraction is associated with higher forage intake and better performance in beef cattle.

Overall, the animals experienced postpartum body condition loss, with continuous weight loss observed until d30, a period in which intake capacity falls short of its potential while lactation demands increase (LOPES et al., 2023; DAVID et al., 2024). From this point onward, adequate forage supply and improvements in pasture quality may have supported individual performance and mitigated the impacts of negative energy balance, allowing for a partial recovery of nutritional status by the end of the evaluation.

The variation in the metabolic profile over time reflects the homeorhetic adjustments required to support late fetal growth (GIONBELLI et al., 2023), parturition, and the transition from gestation to lactation (BAUMGARD et al., 2017). Additionally, it complements the assessment of productive performance, enabling the evaluation of the animals' nutritional status under different levels of restriction (STRYDOM et al., 2008; DIAZ-GONZALEZ; SILVA, 2017). Overall, the metabolites analyzed in our study confirm a more pronounced negative energy balance up to d30, evidenced by lower glucose and serum protein concentrations, as well as a reduction in BHB and NEFA levels.

From d30 and d45 onwards, a partial recovery in IGF-1 and total cholesterol levels were observed, respectively. Higher levels of these metabolites may indirectly contribute to the early resumption of reproductive function by stimulating gonadotropic hormone secretion and follicular growth (CROWE et al., 2014; D'OCCHIO et al., 2019; CARVALHO et al., 2022). This effect was reflected in the DFPO observed in our study, with an average of 16.2 mm, exceeding the threshold considered ideal for achieving high conception rates (RIBEIRO FILHO et al., 2013). Larger follicles indicate a favorable nutritional status, with greater availability of substrates for protein and energy metabolism, thereby promoting reproductive success (RIBEIRO FILHO et al., 2013; READ et al., 2021)

Regarding the variables measured in the calves, our study indicates that maternal reserve mobilization was sufficient to ensure proper development during the final third of gestation, as reflected in birth weight and muscle fiber area, which were similar among calves born to cows receiving different treatments. Additionally, maternal milk production was similar across treatments, which did not contribute to differences in calf performance up to 60 days of age. The adequate levels of proteins and energy metabolites observed in the calves on d1 and d15 suggest efficient colostrogenesis and proper nutritional status (DIAZ-GONZALEZ; SILVA, 2017; WANG et al., 2021). Combined with maternal milk production, these factors contributed to optimized weight gain up to 60 days of age, reaching approximately 800 g/day.

Conclusions

Dry distillers' grains have the potential to partially replace conventional ingredients in supplements for beef cows, such as corn and soybean meal, contributing to the improvement of negative energy balance and prepartum weight gain. Its inclusion, up to 42%, in supplements offered to beef cows in late gestation on low-quality pastures, may optimize animal performance during this critical period.

References

ALMEIDA, D. M. et al. Effects of pre- and postpartum supplementation on lactational and reproductive performance of grazing Nellore beef cows. **Animal Production Science**, v. 61, n. 2, p. 101–107, 22 out. 2020.

BAUMAN, B. D. E.; CURRIE, W. Partitioning of Nutrients During Pregnancy and Lactation: A Review of Mechanisms Involving Homeostasis and Homeorhesis. **Journal of Dairy Science**, v. 63, n. 9, p. 1514–1529, 1 set. 1980.

BAUMGARD, L. H.; COLLIER, R. J.; BAUMAN, D. E. A 100-Year Review: Regulation of nutrient partitioning to support lactation. **Journal of Dairy Science**, v. 100, n. 12, p. 10353–10366, 1 dez. 2017.

BOHNERT, D. W. et al. Late gestation supplementation of beef cows differing in body condition score: effects on cow and calf performance. **Journal of Animal Science**, v. 91, n. 11, p. 5485–5491, nov. 2013.

CARVALHO, R. S. et al. Influence of body condition score and its change after parturition on pregnancy rates to fixed-timed artificial insemination in Bos indicus beef cows. **Animal Reproduction Science**, v. 243, p. 107028, ago. 2022.

CHEN, H. et al. Effect of prepartum dietary energy density on beef cow energy metabolites, and birth weight and antioxidative capabilities of neonatal calves. **Scientific Reports**, v. 12, n. 1, p. 4828, 22 mar. 2022.

CONTRERAS, G. A.; STRIEDER-BARBOZA, C.; RAPHAEL, W. Adipose tissue lipolysis and remodeling during the transition period of dairy cows. **Journal of Animal Science and Biotechnology**, v. 8, n. 41, p. 1–12, 2017.

COSTA, T. C. et al. Ruminal undegradable protein enriched diet during late gestation of beef cows affects maternal metabolism and offspring's skeletal muscle development. **Animal Feed Science and Technology**, v. 291, p. 115400, 1 set. 2022.

CROWE, M. A.; DISKIN, M. G.; WILLIAMS, E. J. Parturition to resumption of ovarian cyclicity: comparative aspects of beef and dairy cows. **Animal**, v. 8, p. 40–53, 1 jan. 2014.

DAVID, G. S. S. et al. Periparturient Changes in Voluntary Intake, Digestibility, and Performance of Grazing Zebu Beef Cows with or without Protein Supplementation. **Animals**, v. 14, n. 11, p. 1710, 6 jun. 2024.

DETMANN, E. et al. Nutritional aspects applied to grazing cattle in the tropics: A review based on Brazilian results. **Semina: Ciências Agrárias**, v. 35, p. 2829, 4 set. 2014.

DETMANN, E. et al. What is the impact of neutral detergent fibre digestibility on productive performance of beef cattle fed tropical forages? **Livestock Science**, v. 290, p. 105608, 1 dez. 2024.

DETMANN, E.; COSTA E SILVA, L. F.; PALMA, M. N. N. **Métodos para análises de alimentos – INCT Ciência Animal**. 2. ed. Visconde do Rio Branco: Suprema, 2021.

DIAZ-GONZALEZ, F. H.; SILVA, S. C. DA. **Introdução à bioquímica clínica veterinária**. [s.l.] Editora da UFRGS, 2017.

D'OCCHIO, M. J.; BARUSELLI, P. S.; CAMPANILE, G. Influence of nutrition, body condition, and metabolic status on reproduction in female beef cattle: A review. **Theriogenology**, v. 125, p. 277–284, fev. 2019.

FERREIRA, M. F. L. et al. Performance, metabolic and hormonal responses of grazing Nellore cows to an energy-protein supplementation during the pre-partum phase. **BMC veterinary research**, v. 16, n. 1, p. 108, 9 abr. 2020.

FRANCO, M. O. et al. Intake, digestibility, and rumen and metabolic characteristics of cattle fed low-quality tropical forage and supplemented with nitrogen and different levels of starch. **Asian-Australasian Journal of Animal Sciences**, v. 30, n. 6, p. 797–803, 28 out. 2016.

GARCÍA-FRANCO, A. et al. United Nations sustainability development goals approached from the side of the biological production of fuels. **Microbial Biotechnology**, v. 14, n. 5, p. 1871–1877, 2021.

GIONBELLI, M. P.; VALADARES FILHO, S. C.; DUARTE, M. S. Nutritional requirements for pregnant and non-pregnant beef cows. Em: VALADARES FILHO, S. C. et al. (Eds.). **Nutrient Requirements of Zebu and Crossbred Cattle - BR-CORTE**. 4. ed. [s.l.] Editora Scienza, 2023. p. 271–292.

HOFFMANN, A. et al. Does the Effect of Replacing Cottonseed Meal with Dried Distiller's Grains on Nellore Bulls Finishing Phase Vary between Pasture and Feedlot? **Animals**, v. 11, n. 1, p. 85, jan. 2021.

LEMASTER, C. T. et al. The effects of late gestation maternal nutrient restriction with or without protein supplementation on endocrine regulation of newborn and postnatal beef calves. **Theriogenology**, v. 87, p. 64–71, 1 jan. 2017.

LIU, K. Chemical Composition of Distillers Grains, a Review. **Journal of Agricultural and Food Chemistry**, v. 59, n. 5, p. 1508–1526, 9 mar. 2011.

LOPES, S. A. et al. Evaluation of nonlinear models to predict milk yield and composition of beef cows: A meta-analysis. **Animal Feed Science and Technology**, v. 294, p. 115455, 1 dez. 2022.

LOPES, S. A. et al. Exigências nutricionais de vacas de corte lactantes e seus bezerros. Em: VALADARES FILHO, S. C. et al. (Eds.). **Exigências Nutricionais de Zebuínos Puros e Cruzados - BR-CORTE**. 4. ed. [s.l.] Editora Scienza, 2023. p. 299–328.

MORENO, D. S. et al. Pre-and postpartum supplementation strategies on the performance and metabolic status of grazing beef cows. **Pesquisa Agropecuária Brasileira**, v. 58, p. 3102, 26 jun. 2023.

MORIEL, P. et al. Maternal prepartum supplementation of protein and energy and body condition score modulated the performance of *Bos indicus*-influenced cow-calf pairs. **Animal Reproduction Science**, v. 262, p. 107433, 1 mar. 2024.

MURILLO, M. et al. Effect of Supplemental Corn Dried Distillers Grains with Solubles Fed to Beef Steers Grazing Native Rangeland during the Forage Dormant Season. **Asian-Australasian Journal of Animal Sciences**, v. 29, n. 5, p. 666–673, maio 2016.

National Research Council – NRC. Nutrient requirements of beef cattle. 7th. ed. [s.l.] Washington: Academic Press, 2000.

PAULINO, M. F. et al. Bovinocultura otimizada. **IX Simpósio de Produção de Gado de Corte**. 1. ed. Anais do IX Simpósio de Produção de Gado de Corte. Viçosa, MG, Brazil. Departamento de Zootecnia, Universidade Federal de Viçosa. Editora Suprema, 2014.

PAULINO, M. F.; DETMANN, E.; VALADARES FILHO, S. C. **VI Simpósio de Produção de Gado de Corte**. 1. ed. Anais do VI Simpósio de Produção de Gado de Corte. Viçosa, Minas Gerais, Brazil. Departamento de Zootecnia, Universidade Federal de Viçosa: Editora Suprema, 2008.

PICANÇO, Y. DOS S. et al. Dried distillers grains in supplements for pasture-fed cattle. **Ciência Animal Brasileira**, v. 25, p. 77990E, 23 set. 2024.

READ, C. C. et al. Correlation between Pre-Ovulatory Follicle Diameter and Follicular Fluid Metabolome Profiles in Lactating Beef Cows. **Metabolites**, v. 11, n. 9, p. 623, set. 2021.

RIBEIRO FILHO, A. L. et al. Diâmetro do folículo no momento da inseminação artificial em tempo fixo e taxa de concepção em vacas nelore. **Ciência Animal Brasileira**, v. 14, n. 4, p. 501–507, 17 dez. 2013.

ROTTA, P. P. et al. Effects of day of gestation and feeding regimen in Holstein × Gyr cows: I. Apparent total-tract digestibility, nitrogen balance, and fat deposition. **Journal of Dairy Science**, v. 98, n. 5, p. 3197–3210, 1 maio 2015.

SARAIVA, D. T. et al. Performance and Metabolic Responses of Nellore Cows Subjected to Different Supplementation Plans during Prepartum. **Animals**, v. 14, n. 16, p. 2283, jan. 2024.

STRYDOM, S. et al. Evaluation of biochemical and ultrasonographic measurements as indicators of undernutrition in cattle. **Onderstepoort Journal of Veterinary Research**, v. 75, n. 3, p. 207–213, 10 set. 2008.

VALADARES FILHO, S. DE C. et al. **CQBAL 4.0**. Tabelas Brasileiras de Composição de Alimentos para Ruminantes. 2023. Disponível em: <https://www.cqbal.com.br/#!/autorescitacoes>. Acesso em: 6 nov. 2024.

WANG, H. et al. Maternal Supply of Ruminally-Protected Lysine and Methionine During Close-Up Period Enhances Immunity and Growth Rate of Neonatal Calves. **Frontiers in Veterinary Science**, v. 8, 2 dez. 2021.

WILSON, T. B.; FAULKNER, D. B.; SHIKE, D. W. Influence of late gestation drylot rations differing in protein degradability and fat content on beef cow and subsequent calf performance. **Journal of Animal Science**, v. 93, n. 12, p. 5819–5828, dez. 2015.

WOOD, K. M. et al. Influence of pregnancy in mid-to-late gestation on circulating metabolites, visceral organ mass, and abundance of proteins relating to energy metabolism in mature beef cows. **Journal of Animal Science**, v. 91, n. 12, p. 5775–5784, dez. 2013.

Tables and Figures

Table 1. Ingredients and nutritional composition of supplements for pregnant Nellore cows in the late gestation, supplemented with different levels of inclusion of dried distillers' grains.

Item	Supplement			
	Control	*0%DDG*	*42%DDG*	*84%DDG*
		g/kg - as feed		
Corn meal	-	477	238	-
Soybean meal	-	363	182	-
DDG	-	-	420	840
Urea AS	-	80	80	80
Mineral mixture[1]	1000	80	80	80
		g/kg - dry matter		
DM[2]	-	855	820	819
OM[2]	-	908	903	907
CP[2]	-	437	437	429
apNDF[2]	-	113	257	413
iNDF[2]	-	15	32	62
RDP[3]	-	342	314	286
RUP[3]	-	72	108	144

[1]Mineral mixture composition: Dicalcium phosphate 300 g/kg, Sodium chloride 253 g/kg, Sulfur flower 33.3 mg/kg, Magnesium oxide 16.7 mg/kg, Zinc sulfate 15.0 mg/kg, Copper sulfate 7.0 mg/kg, Manganese sulfate 5.0 mg/kg, Cobalt sulfate 0.5 mg/kg, Potassium iodide 5.0 mg/kg, Sodium selenite 0.1 mg/kg; [2]DM dry matter, OM organic matter, CP crude protein, apNDF neutral insoluble detergente fiber corrected for ash and protein, iNDF indigestible neutral insoluble detergent fiber; [3]RDP e RUP, rumen degradable protein and rumen undegradable protein (VALADARES FILHO et al., 2023).

Table 2. Nutritional composition of *Urochloa decumbens* and forage availability for pregnant Nellore cows in the late gestation, supplemented with different levels of inclusion of dried distillers' grains.

Item	Month					
	June, d-90	*July, d-60*	*August, d-30*	*September, d0*	*October, d30*	*November, d60*
				g/kg DM		
DM	494	620	641	579	258	268
OM	921	926	931	925	911	906
CP	38	35	33	54	102	87
apNDF	729	757	752	733	620	667
iNDF	295	332	30	341	270	239
				g/kg BW		
fDM	85.2	78.0	62.9	60.4	66.9	75.5
pdDM	58.1	49.6	38.1	37.7	42.0	50.0

DM, dry matter; OM, organic matter; CP, crude protein; apNDF, Neutral detergent fiber corrected for ash and protein; iNDF, Indigestible neutral detergent fiber; fDM, forage dry matter offer; pdDM, potentially digestible forage dry matter offer.

Table 3. Relative variation of body weight, body condition score, ribeye area and rump fat thickness measured during the peripartum of Nellore cows supplemented or not with different levels of dried distillers' grains during the last trimester of gestation.

Item	Treatment[1]				SEM	P-value[2]				
	Control	*0%DDG*	*42%DDG*	*84%DDG*		*SUP*	*L*	*Q*	*Prd*	*Trt × Prd*
Body weight, %					1.103	0.29	0.65	0.047	<0.001	0.07
Prepartum	3.80^{b}	6.33^{ab}	10.20^{a}	5.76^{b}						
Postpartum	-4.10^{ab}	-7.32^{b}	-3.04^{a}	-4.67^{ab}						
Body condition score, %					1.518	0.43	0.52	0.63	<0.001	0.68
Prepartum	-0.20	1.06	4.96	1.87						
Postpartum	-10.48	-10.8	-10.98	-9.78						
Ribeye area, %					3.663	0.65	0.72	0.23	<0.001	0.74
Prepartum	2.92	1.61	3.81	-0.14						
Postpartum	-15.90	-22.50	-13.55	-17.96						
Rump fat thickness, %					8.063	0.67	0.65	0.20	<0.001	0.41
Prepartum	2.49	11.22	19.38	14.75						
Postpartum	-50.98	-65.13	-45.91	-60.12						

[1]The supplements were formulated to contain 40% of CP and were offered daily at a rate of 1 kg/animal for 85 days prior to calving. [2]Effects of supplementation (SUP), linear inclusion (L), quadratic inclusion (Q) of DDG levels, measurement period (Prd) and the interaction between treatment and measurement period (Trt × Prd). [a, b]Means with different superscripts within a row differ from each other at $P<0.05$.

Table 4. Average concentration of serum urea nitrogen, total cholesterol, β-hydroxybutyrate, and non-esterified fatty acids measured during the peripartum period in Nellore cows supplemented or not with different levels of dried distillers' grains during the last trimester of gestation.

Trt[1]	**Days relative to calving**							**SEM**	**P-value**[2]				
	d-30	*d-15*	*d1*	*d15*	*d30*	*d45*	*d60*		*SUP*	*L*	*Q*	*Day*	*Trt × Day*
	Serum urea nitrogen, mg/dL							0.85	0.020	0.005	0.77	<0.001	<0.001
Control	9.1^{B}	8.3^{C}	11.0	8.3^{BC}	11.5	12.4^{AB}	9.1						
0%DDG	16.6^{A}	18.8^{A}	12.5	9.6^{AB}	10.1	14.5^{A}	7.5						
42%DDG	13.3^{A}	13.1^{B}	11.8	12.2^{A}	11.9	9.7^{BC}	8.1						
84%DDG	12.2^{A}	12.5^{B}	13.2	6.6^{C}	11.0	8.9^{C}	8.7						
Overall[3]	27.4^{ab}	28.2^{a}	26.0^{ab}	19.7^{c}	23.8^{b}	24.3^{b}	17.9^{c}						
	Total cholesterol, mg/dL							8.54	0.69	0.50	0.99	<0.001	0.036
Control	144.6	130.7	102.6^{AB}	119.4	121.9^{A}	131	121.2						
0%DDG	149.5	146.7	96.1^{B}	106.9	111.8^{AB}	136.2	124.5						
42%DDG	138.3	131.2	117.9^{AB}	106.3	104.6^{AB}	118.4	131.0						
84%DDG	134.6	132.4	123.0^{A}	100.2	87.6^{B}	127.7	119.1						
Overall[3]	141.7^{a}	135.2^{b}	109.9^{d}	108.2^{d}	106.5^{d}	128.3^{bc}	123.7^{c}						
	β-hidroxybutirate, mmol/L							0.0504	0.62	0.87	0.25	0.004	0.033
Control	0.546^{AB}	0.731^{A}	0.511	0.499	0.479	0.478	0.422						
0%DDG	0.475^{AB}	0.543^{AB}	0.567	0.490	0.546	0.500	0.487						
42%DDG	0.427^{B}	0.436^{B}	0.440	0.522	0.422	0.451	0.445						
84%DDG	0.627^{A}	0.601^{AB}	0.554	0.563	0.400	0.513	0.423						
Overall[3]	0.519^{ab}	0.578^{a}	0.518^{ab}	0.517^{ab}	0.462^{bc}	0.486^{bc}	0.444^{c}						
	Non-esterified fatty acids, mmol/L							0.0482	0.049	0.84	0.39	<0.001	0.012
Control	0.473^{A}	0.606^{A}	1.393^{A}	0.907	0.420	0.157	0.230						
0%DDG	0.139^{B}	0.350^{B}	1.096^{AB}	0.866	0.446	0.25	0.119						
42%DDG	0.149^{B}	0.236^{B}	1.046^{AB}	0.846	0.243	0.123	0.095						

84%DDG	0.402[A]	0.413[AB]	0.875[B]	0.872	0.263	0.169	0.154
Overall[3]	*0.291[d]*	*0.401[c]*	*1.103[a]*	*0.873[b]*	*0.343[cd]*	*0.175[e]*	*0.152[e]*

[1]The supplements were formulated to contain 40% of CP and were offered daily at a rate of 1 kg/animal for 85 days prior to calving. [2]Effects of supplementation (SUP), linear inclusion (L), quadratic inclusion (Q) of DDG levels, measurement period (Day) and the interaction between treatment and measurement period (Trt × Day). [3]Overall means of repeated measures over time. [A, B, C]Means followed by different uppercase superscript letters in the same column differ from each other at P < 0.05. [a, b, c, d, e]Means with different lowercase superscripts letters within a row differ from each other at P < 0.05.

Table 5. Body weight and metabolic profile of calves born to Nellore cows supplemented or not with different levels of dried distillers' grains during the final trimester of gestation.

Item	Treatment[1]				SEM	P-value[2]				
	Control	*0%DDG*	*42%DDG*	*84%DDG*		*SUP*	*L*	*Q*	*Day*	*Trt × Day*
Body weight, kg					2.36	0.35	0.16	0.97	<0.001	0.21
d1	37.6	35.9	36.6	34.9						
d60	86.6	87.8	81.3	77.5						
Total Protein, g/dL					0.23	0.61	0.20	0.64	<0.001	0.21
d1	6.5	6.6	5.7	6.2						
d15	5.5	6.0	5.5	4.7						
Albumin, g/dL					0.02	0.42	0.14	0.73	0.004	0.85
d1	2.2	2.4	2.3	2.1						
d15	2.6	2.6	2.4	2.2						
Globulin, d/dL					0.19	0.80	0.28	0.72	<0.001	0.17
d1	4.3	4.4	3.5	4.0						
d15	2.9	3.3	3.3	2.5						
Glucose, mg/dL					5.03	0.85	0.39	0.71	0.38	0.60
d1	117.9	120.7	128.4	109.1						
d15	112.7	121.9	111.9	111.4						
IGF-1, ng/dL	230.6	244.4	247.9	282.0	19.64	0.32	0.26	0.61	-	-

[1]The supplements were formulated to contain 40% of CP and were offered daily to the calf's dams at a rate of 1 kg/animal for 85 days prior to calving. [2]Effects of supplementation (SUP), linear inclusion (L) and quadratic inclusion (Q) of DDG levels, measurement period (Day) and the interaction between treatment and measurement period (Trt × Day). Sex and the interactions with treatment and day were not significant (P > 0.05).

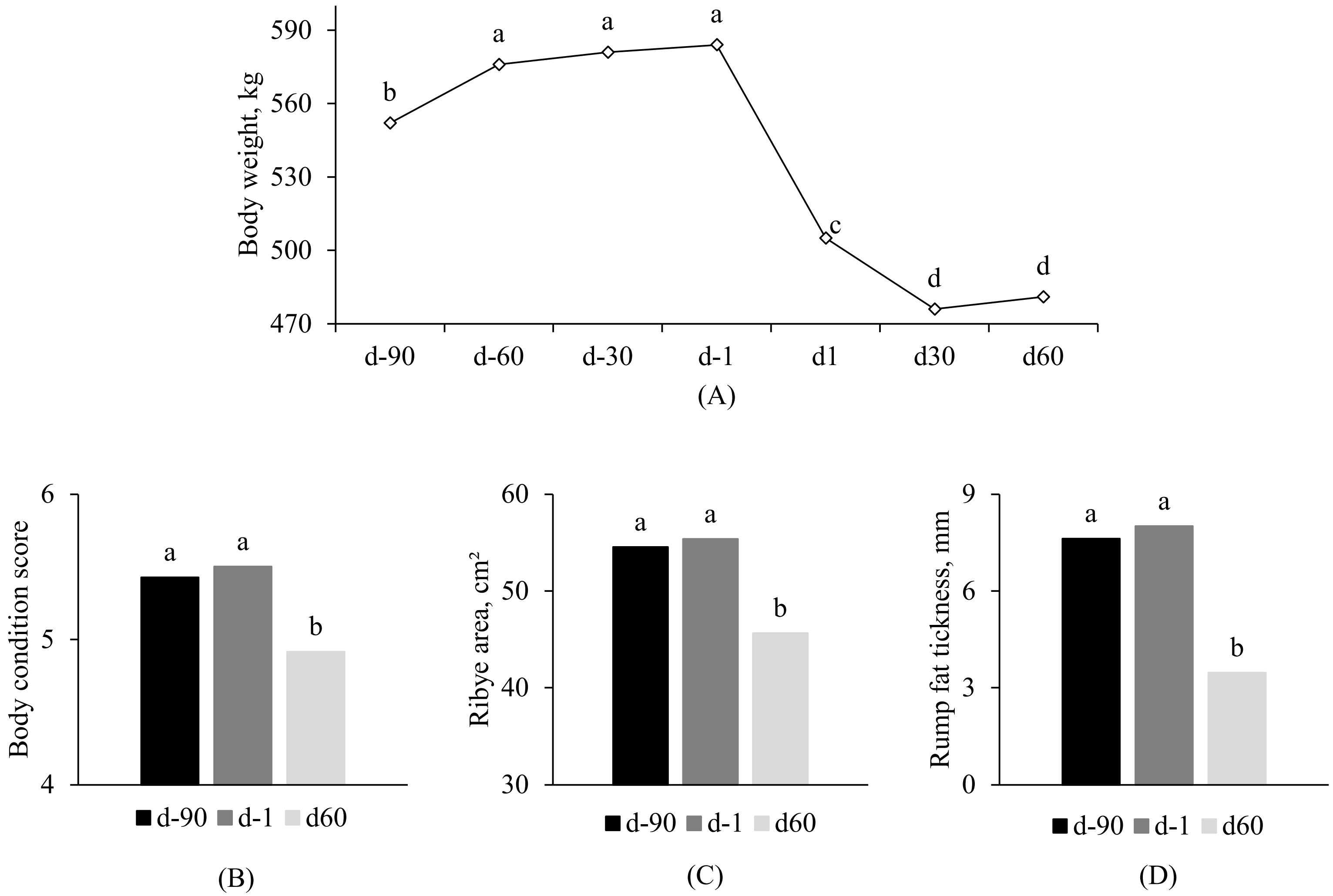

Figure 1. Body weight (A), body condition score (B), ribeye area (C), and rump fat thickness (D) measured throughout the peripartum period of Nellore cows supplemented or not with different levels of dried distillers' grains during the last trimester of gestation. There was no treatment effect (P>0.05) and no interaction between treatment and time (P>0.05). [a, b, c, d]Repeated measures over time followed by different letters differ from each other with P<0.05.

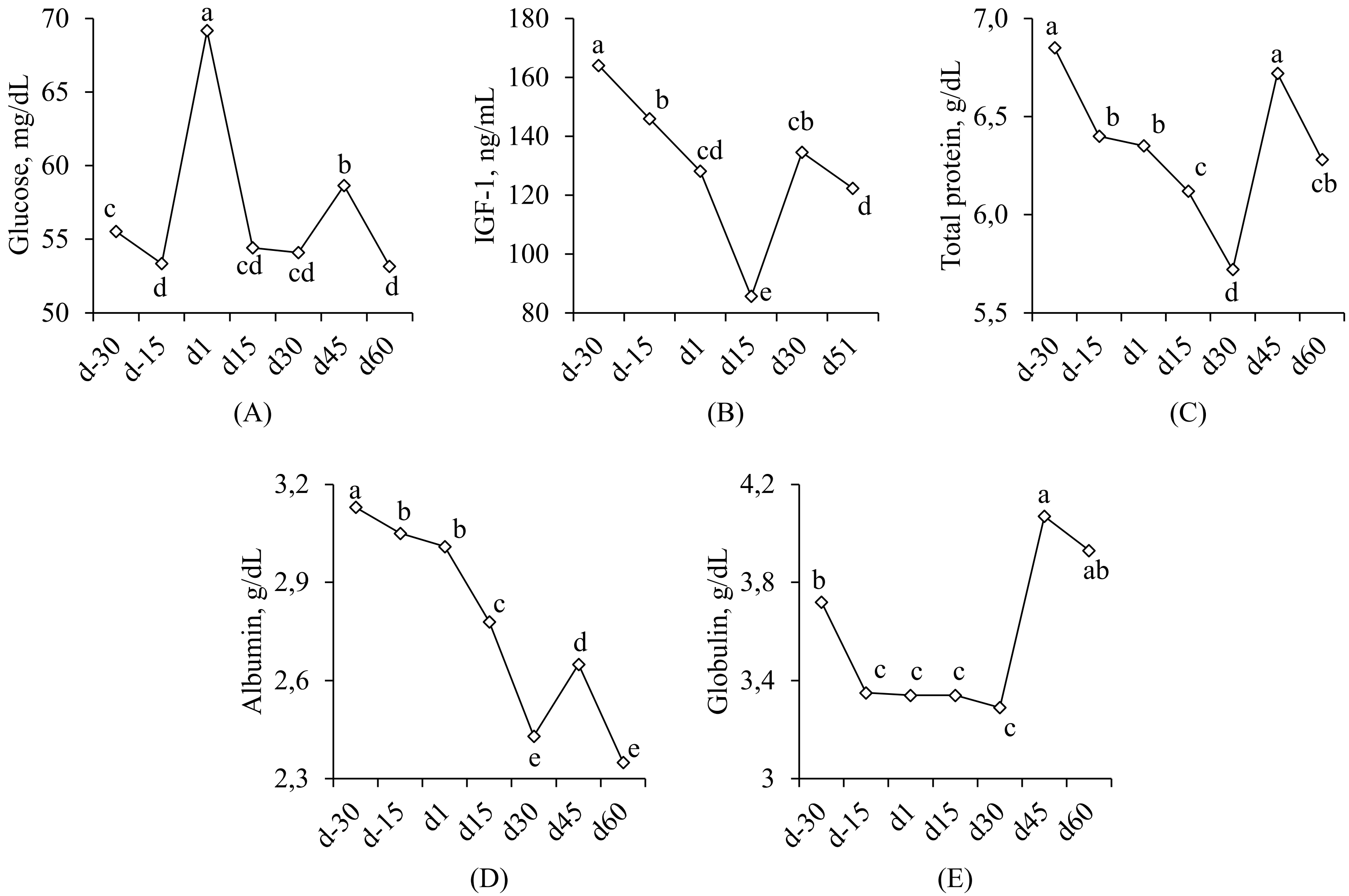

Figure 2. Concentrations of Glucose (A), Insulin-like Growth Factor 1 (IGF-1) (B), Total Proteins (C), Albumin (D), and Globulin (E) in beef cows either unsupplemented or supplemented during the final third of gestation with different levels of DDG. There was no treatment effect (P>0.05) and no interaction between treatment and measurement day (P>0.05). [a, b, c, d, e]Repeated measures over time followed by different letters differ from each other with P<0.05.

CHAPTER 2 - DOES SUPPLEMENTATION INFLUENCE THE PERFORMANCE OF COW-CALF BEEF CATTLE GRAZING ON TROPICAL PASTURES?

Abstract

Our objective was to evaluate the effects of peripartum supplementation of cows and their suckling calves, all of Nellore breed, on tropical pastures, on productive performance through a meta-analysis. Data were obtained from many experiments conducted in Federal University of Viçosa, Brazil, between 2014 and 2023. Analyses were performed using meta-analytic techniques. Cows supplemented during the prepartum period showed greater variation in body weight (BW) ($P<0.10$) and, consequently, had higher BW at calving ($P<0.10$), in addition to a positive change in body condition score (BCS) ($P<0.10$). However, when supplementation was not continued postpartum, cows supplemented only during the prepartum period experienced greater BW loss in the postpartum period ($P<0.10$). Peripartum supplementation did not influence BW or BCS at the beginning of the breeding season ($P>0.10$). The supplementation strategy did not affect reproductive rates at the end of the breeding season or milk production ($P>0.10$). On the other hand, cows supplemented exclusively during the postpartum period showed higher pregnancy rates at first insemination ($P<0.10$). Maternal supplementation did not affect calf birth weight ($P>0.10$) or weaning weight ($P>0.10$). However, calves that received creep-feeding had higher weaning weight ($P<0.10$). In conclusion, prepartum supplementation is effective in improving cow performance during this period. Meanwhile, exclusive postpartum supplementation enhances reproductive efficiency, resulting in higher pregnancy rates at the beginning of the breeding season. Additionally, the use of creep-feeding proves to be an effective strategy to increase productivity in cow-calf systems.

Keywords: Nellore cows, creep feeding, periparturient, tropical forage, body condition score, negative energy balance

Introduction

The body condition and nutritional status of cows during the final third of gestation, calving, and the breeding season are crucial for the success of beef cattle production (D'OCCHIO et al., 2019; CARVALHO et al., 2022). In tropical pasture-based systems, in addition to this period being characterized by seasonal forage quality, the transition in the physiological stage of pregnant cows implies greater requirements for fetal development (GIONBELLI et al., 2023) and early lactation (LOPES et al., 2023).

The availability of nitrogen in the rumen is essential for extracting energy from low-quality fibrous compounds (DETMANN et al., 2014). Additionally, for pregnant cows, higher energy intake during this period is directly related to body reserve formation and proper fetal development (CHEN et al., 2022; SARAIVA et al., 2024), which is subsequently associated with improved reproductive performance and meat production. Therefore, protein or protein-energy supplementation during the peripartum period can be a crucial strategy to overcome nutritional challenges and increase productive efficiency in cow-calf systems.

Some studies have reported contrasting effects of protein-energy supplementation during the final third of gestation (FERREIRA et al., 2020; SARAIVA et al., 2024) and/or the postpartum period (ALMEIDA et al., 2020), sometimes yielding beneficial effects on productive and reproductive performance, and at other times not. These discrepancies may be attributed to environmental factors, such as forage availability and quality, which vary from year to year, as well as the low number of experimental units used in individual studies (MORIEL et al., 2024). Under these conditions, a meta-analytical approach can be employed to increase the number of observations and incorporate data from beef cows under different conditions across multiple years.

This meta-analysis aims to evaluate different protein-energy supplementation strategies for beef cows during the peripartum period under tropical conditions and their effects on body condition changes, progeny development, and pregnancy rates. Additionally, we seek to analyze the impact of the creep-feeding strategy on the performance of beef calves.

Materials and Methods

This study used data from previously published papers and did not require an approval from the Animal Care and Use Committee of the Federal University of Viçosa to be performed.

Data acquisition

The dataset used to evaluate milk production, BCS, body weight (BW), and pregnancy rate of Nellore cows and their calves included a total of 29 experiments conducted between 2014 and 2023 under tropical conditions in Brazil. These experiments were carried out in the Department of Animal Science at the Federal University of Viçosa, Brazil (20° 45′ S, 42° 52′ W), in an area consisting of 17 paddocks uniformly covered with *Urochloa decumbens* for continuous grazing. Each paddock was equipped with drinking troughs and covered feeding troughs. Additionally, covered creep feeders with restricted access were available for the calves. The cows and cow-calf pairs were managed under a stocking rate of 1.0 to 1.5 animal units per hectare.

In general, the duration range of experiments with cows spanned from 190 days of gestation to 70 days postpartum, covering the final third of gestation and the onset of the breeding season. The supplemented treatments consisted of offering a protein-energy supplement during the prepartum, postpartum, or both periods, with crude protein concentrations ranging from 20% to 40% as feed basis. For creep experiments, crude protein concentrations ranged from 15% to 30% as feed basis. In general, creep supplementation started between 90 and 120 days of calves' age and continued until weaning, which occurred around 210 to 240 days. For both cow and calf experiments, the control treatment consisted of providing a mineral mixture *ad libitum*. Information regarding the level of supplement supply, the individual duration of the supplementation period, and the respective references can be found in Table 1 and Appendix, respectively.

In all experiments, the BCS of the cows was assessed by experienced evaluators using a 1 to 9 scale (NRC, 2000), at the late gestation (around 190 days of gestation), at calving, and at the beginning of the breeding season (around 70 days postpartum). Additionally, the cows were weighed without fasting on the same dates, and the calves were weighed at birth, at begin of creep and at weaning. To minimize potential differences between cows from different experiments, the variations in BCS and BW pre and postpartum were calculated using the following equations:

$$PreBW\ change = \frac{(\text{BW at calving} - \text{Initial BW})}{\text{Initial BW}}\ x\ 100 \quad (1)$$

$$PostBW\ change = \frac{(\text{Final BW} - \text{BW at calving})}{\text{BW at calving}} \text{ x } 100 \quad (2)$$

$$PreBCS\ change = \frac{(\text{BCS at calving} - \text{Initial BCS})}{\text{Initial BCS}} \text{ x } 100 \quad (3)$$

$$PostBCS\ change = \frac{(\text{Final BCS} - \text{BCS at calving})}{\text{BCS at calving}} \text{ x } 100 \quad (4)$$

where: PreBW change and PreBCS change: change in body weight or body condition score in late gestation; BW at calving: body weight on the expected calving date; Initial BW and Initial BCS: initial body weight or body condition score of cows in late gestation; PostBW change and PostBCS change: change in body weight or body condition score from calving to beginning of the breeding season; BW at calving and BCS at calving: body weight or body condition score measured on the expected calving date. Final BW and Final BCS: body weight or body condition score at beginning of the breeding session.

Milk production was measured at approximately 25 and 50 days of lactation using a milking machine. In all experiments, milk production was assessed after the separation of cows and calves, with previously controlled suckling. The cows were milked 12 hours after separation, following the administration of 1 mL of oxytocin (10 IU/mL; Ocitovet, Brazil) into the mammary vein, and the milk obtained was weighed. The exact time from separation to the completion of milking for each cow was recorded, and milk production was proportionally converted to a 24-hour yield (LOPES et al., 2022).

The breeding season began approximately 70 days postpartum and involved two inseminations. The cows were synchronized using IATF protocols and inseminated with semen from Nellore bulls randomly assigned to each cow. Pregnancy diagnosis was performed, in general, 30 days after insemination, confirming pregnancies resulting from the first and second inseminations.

Statistical analysis

The data were analyzed according to meta-analysis techniques (ST-PIERRE, 2001; TEMPELMAN, 2024) using the GLIMMIX procedure of SAS 9.4. For the prepartum measurements, the basic model included the fixed effects of cows' supplementation (with or without supplementation), sex of the calves (male or female), and their interaction. For the postpartum measurements, the basic model included the fixed effects of prepartum cows' supplementation (with or without), postpartum cows' supplementation (with or without), sex of the calves (male or female), and their interaction. For calves' weaning weight, the effect of creep-feeding supplementation was also included in the model. Due to the lower number and uneven distribution of milk yield observations, the estimation of the interaction effects was compromised. Then, for this response variable, the basic model contained only the main fixed effects described above, without any interaction. The random effect of the different experiments was considered in the parameter estimation. The best (co)variance structures were evaluated using the Akaike information criterion with correction. A normal distribution of errors was used for all variables, excepted for pregnancy rates, where a binomial distribution of errors was used (STROUP, 2013). Statistical significance was declared at P<0.10.

Results

Pre-partum evaluations

There was no interaction (P>0.10) between prepartum supplementation and calf sex on the cow-calf pair performance (Table 3). The cows' BCS change was affected by supplementation during the prepartum (P=0.085), being positive for supplemented cows and negative for non-supplemented cows. Supplemented cows were heavier on parturition (P<0.001). Additionally, the BW change was lower for supplemented cows (P<0.001) during the prepartum period. The calves' birth weight was not influenced by cows' supplementation (P=0.18). In general, male calves were heavier than female calves (P<0.01).

Post-partum evaluations

No effects were detected on the postpartum BCS, BCS change and cows' BW (P>0.10, Table 4). However, postpartum BW change showed an interaction between pre and postpartum supplementation (P=0.048). The slicing of this effect showed that cows that were supplemented in the pre-partum lost weight when not supplemented in the post-partum period (P<0.01). No effect was observed on milk yield (P>0.10, Figure 1). The calves' weaning weight was affected only by sex (P=0.004, Figure 2) and creep supplementation (P<0.01, Figure 2), without any effect of cow's supplementation or respective interactions (P>0.10).

The pregnancy rate at first insemination presented an interaction between pre and postpartum supplementation (P=0.054, Figure 3). The slicing of this effect revealed that the exclusive postpartum supplementation increased pregnancy rate when compared to cows supplemented in both pre and post-partum (P=0.047). Despite of this pattern, no effect was detected (P>0.10) on final pregnancy rate after second fixed time artificial insemination (Figure 4).

Discussion

In cows, advancing gestation is associated with reduced feed intake, uterine growth, and a reduction in the size of organs and viscera (WOOD et al., 2013; ROTTA et al., 2015; DAVID et al., 2024). Homeorhetic adaptations during this period prioritize the development of gestational components and mammary gland (GIONBELLI et al., 2023). When nutritional demands are not met and cows have an adequate BCS, body reserves are mobilized to prevent fetal development impairment. Also, in severe condition, protein-energy supplementation can mitigate the effects of nutritional restriction on progeny development (LEMASTER et al., 2017; ALMEIDA et al., 2020). This is consistent with the results of our study, where the cows in general began with an adequate BCS, around 5.48 points (Table 2), and non-supplemented cows in the prepartum period had lower parturition weight, greater weight loss and greater reductions in BCS during prepartum, while calves' birth weight was not affected by dams' supplementation, indicating higher mobilization of body reserves to meet gestational demands.

Prepartum supplementation was effective in improving BW and BCS changes. However, when this supplementation was not maintained postpartum, a greater negative weight variation was observed in these animals. Although prepartum supplementation did not lead to a significant increase in body reserves, this can be attributed to the higher maintenance requirements of these cows, as energy demands are directly proportional to BW and BCS (GIONBELLi et al., 2023; LOPES et al., 2023). Despite the greater postpartum weight loss observed in cows that were no longer supplemented, the nutritional strategy did not significantly influence BW or BCS at the onset of the breeding season.

Some studies have documented improvements in BCS and BW postpartum in cows supplemented during the prepartum period. These differences may be attributed to forage quality and availability, the level and profile of the supplement provided, as well as intrinsic factors related to the animals, such as body condition, breed, and frame size. For instance, Saraiva et al. (2024) reported improved performance in cows subjected to moderate to high levels of prepartum supplementation, while low supplementation levels did not promote significant changes in body reserves during the peripartum.

The ideal nutritional status during the postpartum period, reflected in an adequate BCS, is associated with a cascade of hormonal reactions responsible for better reproductive rates during the breeding season (D'OCCHIO et al., 2019). There is evidence, for example, of higher conception rates when progesterone increases before the first estrus after calving (WERTH et al., 1996), and in tropical conditions, Saraiva et al. (2024) demonstrated that cows receiving a moderate to higher supplemental plan during pre-partum (above 4 g/kg BW) showed higher condition score and progesterone levels in postpartum. Additionally, BCS at calving is one of the main determinants of pregnancy rates in cows. When body condition score is above 5.0, moderate loss until the breeding season is considered acceptable to maintain good reproductive performance (MORIEL et al., 2024). On the other hand, cows that mobilize more body reserves up to calving, have lower energy requirements in postpartum period and are therefore more responsive to supplementation or forage availability. This explains the similar postpartum performance and reproductive rates between cows that were not supplemented during the peripartum period and those supplemented only prepartum, as one group mobilized more body reserves during the postpartum period, while the other was able to regain body reserves and improve nutritional status.

The reason why cows supplemented both in the prepartum and postpartum periods presented lower pregnancy rates at first insemination remains uncertain. The effects of overfeeding and adequate body condition on reproductive parameters, particularly in dairy cows, are well documented in the review by Sartori and Guardieiro (2010), which reported that increased hepatic metabolic activity, enhanced steroid hormone clearance, and hyperinsulinemia were associated with prolonged follicular waves, delayed ovulation, reduced estrus duration and intensity, and lower endocrine and nutritional support for early pregnancy maintenance. However, overfeeding is not commonly designated for grazing beef cattle receiving supplementation.

There are few to no studies addressing the ingestive behavior of beef cows subjected to the interruption of supplementation. However, it is well established that the provision of concentrate feed can influence the ingestive behavior of grazing cattle, even reducing forage intake (CABRAL et al., 2011). Animal habituation can be understood as a decreased behavioral response to repeated stimuli (RANKIN et al., 2009), and extrapolating to our results, it is possible that cows supplemented continuously during the pre- and postpartum periods became habituated to this condition, thereby reducing their daily forage intake after supplementation was withdrawn.

Thus, with the cessation of supplementation following insemination may have reduced energy intake, exacerbating the negative energy balance and impairing reproductive performance at the first insemination attempt. This is corroborated by Carvalho et al. (2022), who found higher pregnancy losses in cows that lost condition score after insemination. In contrast, cows supplemented only during the postpartum period, in addition to not becoming accustomed to supplementation, benefited from the improvement in nutritional status promoted by the supplement. This was due to calving with lower body weight, resulting in lower maintenance requirements, which allowed for better energy partitioning towards reproductive processes. Finally, it is noteworthy that, despite the lower conception rates at first insemination, the overall conception rate was similar between supplementation strategies when the entire breeding season was considered (Figure 4), corroborating the fact that maintaining an adequate body condition throughout the peripartum and reproduction period is the key determinant of reproductive success in beef cows (CARVALHO et al., 2022; MORIEL et al., 2024).

Prepartum supplementation has shown varied results regarding calf performance. Some studies found no significant benefits (MULLINIKS et al., 2013; QUINTANS et al., 2015; SHOUP et al., 2015), while others indicated improvements in weaning weight (STALKER et al., 2007; MORIEL et al., 2024). The effects of prepartum supplementation on progeny performance are believed to be linked to the correction of negative impacts caused by maternal nutritional restriction during gestation, as well as an increase in the cow's body reserves and nutritional status, which may promote greater subsequent milk production. However, studies have shown that supplementing cows with an adequate BCS at the end of gestation, as well as calf sex, has little or no impact on milk production (LARSON et al., 2009; QUINTANS et al., 2015; SHOUP et al., 2015; LOPES et al., 2016) and it was corroborated with our results.

Regarding postpartum supplementation, McLean et al. (2018) observed better calf performance when supplementation was provided after calving (approximately 3 g/kg of BW), compared to prepartum supplementation. However, Astessiano et al. (2013) found no benefits in calf performance with postpartum supplementation for 21 days. Furthermore, the intake capacity of Nellore cows tends to be limited, though increasing, until the third week postpartum (DAVID et al., 2024). This suggests that postpartum supplementation with low to moderate intake, over a short period, may have a limited impact on milk production and, consequently, on calf performance, especially when the forage quality is moderate to high.

The improved performance of calves receiving creep aligns with the literature data. In a meta-analysis study, Carvalho et al. (2019) found a quadratic effect of calf supplementation on tropical pastures, with a maximum additional gain of 0.2 kg/day for males and 0.1 kg/day for females, compared to non-supplemented calves. These increments may be associated with the better nutritional value of the concentrate consumed compared to the forage source, as some level of forage substitution can occur when protein-energy supplements are provided to this category (LOPES et al., 2017).

Conclusions

Prepartum supplementation for beef cows in tropical condition can change the body reserves and weight at parturition but also leads to greater mobilization of these reserves in the postpartum period when the strategy is not maintained. On the other hand, cows supplemented exclusively in the postpartum period tend to allocate more energy towards reproduction. This factor can lead to earlier conception and higher pregnancy rates at the beginning of the breeding season, which is associated with earlier calving and improved productivity in cow-calf systems.

Low to moderate levels of supplementation during the final third of gestation do not significantly impact calf performance until weaning. In contrast, exclusive supplementation through creep feeding has strong potential to enhance calf performance during the nursing phase, accelerating the production cycle.

References

ALMEIDA, D. M. et al. Effects of pre- and postpartum supplementation on lactational and reproductive performance of grazing Nellore beef cows. **Animal Production Science**, v. 61, n. 2, p. 101–107, 22 out. 2020.

ASTESSIANO, A. L. et al. Metabolic, productive and reproductive responses to postpartum short-term supplementation in primiparous beef cows. **Revista Brasileira de Zootecnia**, v. 42, p. 246–253, abr. 2013.

BOHNERT, D. W. et al. Late gestation supplementation of beef cows differing in body condition score: effects on cow and calf performance. **Journal of Animal Science**, v. 91, n. 11, p. 5485–5491, nov. 2013.

CABRAL, C. H. A. et al. Comportamento ingestivo diurno de novilhos suplementados no período das águas. **Revista Caatinga**, v. 24, n. 4, p. 178–185, 14 set. 2011.

CARVALHO, R. S. et al. Influence of body condition score and its change after parturition on pregnancy rates to fixed-timed artificial insemination in Bos indicus beef cows. **Animal Reproduction Science**, v. 243, p. 107028, ago. 2022.

CARVALHO, V. V. et al. A meta-analysis of the effects of creep-feeding supplementation on performance and nutritional characteristics by beef calves grazing on tropical pastures. **Livestock Science**, v. 227, p. 175–182, 1 set. 2019.

CHEN, H. et al. Effect of prepartum dietary energy density on beef cow energy metabolites, and birth weight and antioxidative capabilities of neonatal calves. **Scientific Reports**, v. 12, n. 1, p. 4828, 22 mar. 2022.

COOKE, R. F. et al. Effects of body condition score at initiation of the breeding season on reproductive performance and overall productivity of *Bos taurus* and *B. indicus* beef cows. **Animal Reproduction Science**, v. 232, p. 106820, 1 set. 2021.

DAVID, G. S. S. et al. Periparturient Changes in Voluntary Intake, Digestibility, and Performance of Grazing Zebu Beef Cows with or without Protein Supplementation. **Animals**, v. 14, n. 11, p. 1710, 6 jun. 2024.

DETMANN, E. et al. Nutritional aspects applied to grazing cattle in the tropics: A review based on Brazilian results. **Semina: Ciências Agrárias**, v. 35, p. 2829, 4 set. 2014.

D'OCCHIO, M. J.; BARUSELLI, P. S.; CAMPANILE, G. Influence of nutrition, body condition, and metabolic status on reproduction in female beef cattle: A review. **Theriogenology**, v. 125, p. 277–284, fev. 2019.

FERREIRA, M. F. L. et al. Performance, metabolic and hormonal responses of grazing Nellore cows to an energy-protein supplementation during the pre-partum phase. **BMC veterinary research**, v. 16, n. 1, p. 108, 9 abr. 2020.

GIONBELLI, M. P.; VALADARES FILHO, S. C.; DUARTE, M. S. Nutritional requirements for pregnant and non-pregnant beef cows. Em: VALADARES FILHO, S. C. et al. (Eds.). **Nutrient Requirements of Zebu and Crossbred Cattle - BR-CORTE**. 4. ed. [s.l.] Editora Scienza, 2023. p. 271–292.

LARSON, D. M. et al. Winter grazing system and supplementation during late gestation influence performance of beef cows and steer progeny. **Journal of Animal Science**, v. 87, n. 3, p. 1147–1155, mar. 2009.

LEMASTER, C. T. et al. The effects of late gestation maternal nutrient restriction with or without protein supplementation on endocrine regulation of newborn and postnatal beef calves. **Theriogenology**, v. 87, p. 64–71, 1 jan. 2017.

LOPES, S. A. et al. Evaluation of supplementation plans for suckling beef calves managed on tropical pasture. **Semina: Ciências Agrárias**, v. 38, n. 2, p. 1027–1040, 2 maio 2017.

LOPES, S. A. et al. Evaluation of nonlinear models to predict milk yield and composition of beef cows: A meta-analysis. **Animal Feed Science and Technology**, v. 294, p. 115455, 1 dez. 2022.

LOPES, S. A. et al. Exigências nutricionais de vacas de corte lactantes e seus bezerros. Em: VALADARES FILHO, S. C. et al. (Eds.). **Exigências Nutricionais de Zebuínos Puros e Cruzados - BR-CORTE**. 4. ed. [s.l.] Editora Scienza, 2023. p. 299–328.

MCLEAN, K. J. et al. The effects of protein supplementation of fall calving beef cows on pre- and postpartum plasma insulin, glucose and IGF-I, and postnatal growth and plasma insulin and IGF-I of calves. **Journal of Animal Science**, v. 96, n. 7, p. 2629–2639, jul. 2018.

MORIEL, P. et al. Maternal prepartum supplementation of protein and energy and body condition score modulated the performance of *Bos indicus*-influenced cow-calf pairs. **Animal Reproduction Science**, v. 262, p. 107433, 1 mar. 2024.

MULLINIKS, J. T. et al. Supplementation strategy during late gestation alters steer progeny health in the feedlot without affecting cow performance. **Animal Feed Science and Technology**, v. 185, n. 3, p. 126–132, 25 out. 2013.

National Research Council – NRC. Nutrient requirements of beef cattle. 7th. ed. [s.l.] Washington: Academic Press, 2000.

QUINTANS, G. et al. Influence of a short-term prepartum supplementation on beef cows and calves' performance in pastoral conditions. **Animal Production Science**, v. 56, n. 11, p. 1913–1919, 15 set. 2015.

RANKIN, C. H. et al. Habituation revisited: An updated and revised description of the behavioral characteristics of habituation. **Neurobiology of Learning and Memory**, Special Issue: Neurobiology of Habituation. v. 92, n. 2, p. 135–138, 1 set. 2009.

ROTTA, P. P. et al. Effects of day of gestation and feeding regimen in Holstein × Gyr cows: I. Apparent total-tract digestibility, nitrogen balance, and fat deposition. **Journal of Dairy Science**, v. 98, n. 5, p. 3197–3210, 1 maio 2015.

SARAIVA, D. T. et al. Performance and Metabolic Responses of Nellore Cows Subjected to Different Supplementation Plans during Prepartum. **Animals**, v. 14, n. 16, p. 2283, jan. 2024.

SARTORI, R.; GUARDIEIRO, M. M. Fatores nutricionais associados à reprodução da fêmea bovina. **Revista Brasileira de Zootecnia**, v. 39, p. 422–432, jul. 2010.

SHOUP, L. M. et al. Prepartum supplement level and age at weaning: I. Effects on pre- and postpartum beef cow performance and calf performance through weaning. **Journal of Animal Science**, v. 93, n. 10, p. 4926–4935, out. 2015.

STALKER, L. A. et al. Effects of Weaning Date and Prepartum Protein Supplementation on Cow Performance and Calf Growth. **Rangeland Ecology & Management**, v. 60, n. 6, p. 578–587, 1 nov. 2007.

ST-PIERRE, N. R. *Invited Review:* Integrating Quantitative Findings from Multiple Studies Using Mixed Model Methodology1. **Journal of Dairy Science**, v. 84, n. 4, p. 741–755, 1 abr. 2001.

STROUP, W. W. **Generalized linear mixed models: Modern concepts, methods and applications**. Boca Raton: CRC Press, Taylor & Francis, 2013.

TEMPELMAN, R. J. INVITED REVIEW: A review of some commonly used meta-analysis methods in dairy science research. **Journal of Dairy Science**, 21 dez. 2024.

WERTH, L. A. et al. Relationship between circulating progesterone and conception at the first postpartum estrus in young primiparous beef cows. **Journal of Animal Science**, v. 74, n. 3, p. 616–619, mar. 1996.

WOOD, K. M. et al. Influence of pregnancy in mid-to-late gestation on circulating metabolites, visceral organ mass, and abundance of proteins relating to energy metabolism in mature beef cows. **Journal of Animal Science**, v. 91, n. 12, p. 5775–5784, dez. 2013.

Tables and Figures

Table 1. Description of the experiments that had data used in the meta-analysis.

Autorship[1]	Supplementation		
	Strategy	*Duration, days*	*Offer*
Abreu, 2020	Pre	90	2 g/kg BW
Albuquerque, in progress	Pre	85	2 g/kg BW
Almeida et al., 2020	Pre, post and both	90 pre and/or 90 post	1 kg/cow
Calderaro et al., 2024	Pre	60	0.5, 1.0 or 1.5 kg/cow
David et al., 2024	Both	60 pre and 40 post	1 kg/cow
Ferreira et al., 2020	Pre	60	1.5 kg/cow
Garcés-Cardenas, 2017	Pre, post and both	60 pre and/or 60 post	1 kg/cow
Ferreira et al., 2021	Pre	60	1 kg/cow
Gonçalves, in progress	Pre	85	1 kg/cow
Lopes et al., 2016	Post	85	1 kg/cow
Moreno et al., 2023a	Pre, post and both	84	1.5 kg/cow
Santos, 2021	Pre	60	1.5 kg/cow
Saraiva et al., 2024	Pre	60	2, 4 or 6 g/kg BW
Silva et al., 2017a	Pre	90, 60 and/or 30	1.0, 1.5 or 3.0 kg/cow
Trece, 2017	Pre, post and both	93 pre and/or 71 post	2 g/kg BW
Abreu, 2020	Creep	140	6 g/kg BW
Almeida, in progress		117	6 g/kg BW
Carvalho et al., 2018		140	10 g/kg BW
Ferreira et al., 2021		113	5 g/kg BW
Lage, 2019		112	8 g/kg BW
Lopes et al., 2017		140	3, 6 or 9 g/kg BW
Martins, 2017		142	5 or 10 g/kg BW
Matos, in progress		108	7 g/kg BW
Moreira, 2022		120	5 g/kg BW
Moreno et al., 2023b		150	5 g/kg BW
Paula et al., 2022		112	6 g/kg BW
Saraiva, 2023		140	5 or 10 g/kg BW
Silva et al., 2017b		120	3 or 6 g/kg BW
Silva, 2018		140	7 g/kg BW

[1]The references are listed in the Appendix.

Table 2. Descriptive statistics of the database utilized to assess the effects of pre and post-partum cows' supplementation

Item	n	Mean	s	Minimum	Maximum
Initial BCS	546	5.48	0.785	4.00	8.70
Initial BW, kg	544	526	60.0	373	755
BCS at calving	495	5.49	0.957	3.50	9.00
Pre-partum BCS change, %	464	1.13	11.319	-33.3	36.4
BW at calving, kg	504	503	56.6	365	699
Pre-partum Bw change, %	471	-4.15	6.313	-28.0	20.4
Final BCS	405	5.16	0.782	3.00	7.50
Post-partum BCS change, %	395	-3.40	10.702	-40.0	36.8
Final BW, kg	497	496	54.2	344	668
Post-partum BW change, %	493	-1.02	6.523	-23.0	28.1
Milk yield, kg/d	283	7.00	2.067	1.00	12.7
Calf birth weight, kg	500	34.3	5.22	19.0	50.0
Calf weaning weight, kg	498	243	36.2	139	349

BCS = body condition score (scale 1-9), BW = body weight, Initial BCS = body condition score at 190 days of gestation, Initial BW = body weight of cows at 190 days of gestation, Pre-partum BCS change = change in body condition score from 190 days of gestation to calving, Pre-partum BW change = change in body weight from 190 days of gestation to calving, Final BCS = body condition score at 70 days postpartum (start of breeding season), Postpartum BCS change = change in body condition score from calving to 70 days postpartum, Final BW = body weight of the cows at 70 days postpartum (start of breeding season), Postpartum BW change = change in body weight from calving to 70 days postpartum, Milk yield (kg/d), calf birth weight (kg) and calf weaning weight = calves were weaned at 7 to 8 months of age.

Table 3. Effect of cow's pre-partum supplementation and calf sex on cow performance during pre-partum and calf birth weight.

Item[2]	Supplementation[1]				RSD	P-Value		
	Without		With					
	Female	*Male*	*Female*	*Male*		*Sup*	*Sex*	*Sup × Sex*
BCS at calving	5.36	5.36	5.56	5.46	0.646	0.16	0.87	0.55
Pre BCS change, %	-0.94	-0.86	3.53	1.72	8.928	0.085	0.77	0.47
BW at calving	483	500	507	511	52.9	<0.001	0.27	0.23
Pre BW change, %	-7.10	-5.35	-3.44	-3.47	5.013	<0.001	0.63	0.16
Calf birth weight, kg	32.5	35.4	33.4	36.3	4.68	0.18	<0.001	0.94

[1]Cow supplementation = pre-partum supplementation around 2 g/kg BW, [2]BCS = Body condition score (scale 1-9), BW = body weight, Pre-partum BCS change = change body condition score from 190 days of gestation to calving (%) and Pre-partum BW change = change in body weight from 190 days of gestation to calving (%).

Table 4. Effect of cow's pre-partum and/or postpartum supplementation and calf sex on cow performance during postpartum.

Pre	**Post**	**Sex**	**Item**			
			Final BCS	*Post BCS change, %*	*Final BW*	*Post BW change, %*
Without	Without	Male	5.14	-3.27	496	-0.06
		Female	5.16	-1.34	486	0.65
	With	Male	4.98	-3.19	494	0.48
		Female	5.07	-0.80	494	1.10
With	Without	Male	5.27	-3,66	498	-2.77
		Female	5.36	-4.52	500	-1.88
	With	Male	5.13	-3.77	510	1.49
		Female	5.11	-0,29	501	0.16
	RSD		0.632	8.637	52.6	4.680
			P-Value			
	Pre		0.41	0.44	0.19	0.10
	Post		0.51	0.73	0.53	0.41
	Sex		0.66	0.17	0.63	0.74
	Pre × Post		0.78	0.47	0.81	0.048
	Pre × Sex		0.91	0.69	0.90	0.45
	Post × Sex		0.92	0.34	0.94	0.39
	Pre × Pos × Sex		0.63	0.36	0.42	0.33

Pre = prepartum supplementation of cows around 2 g/kg BW. Post = postpartum supplementation of cows around 2 g/kg BW.

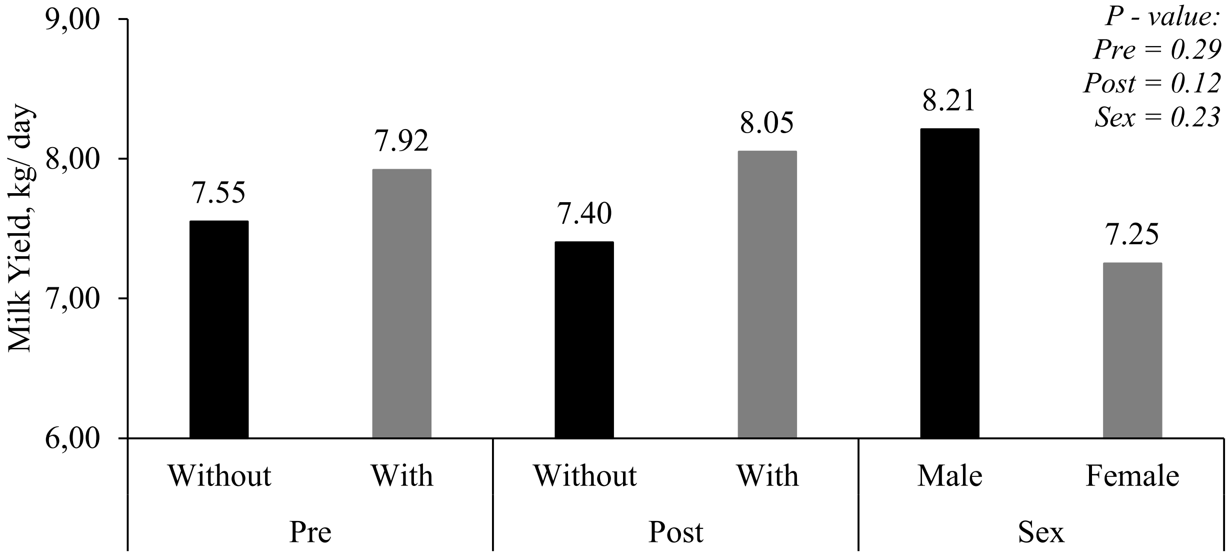

Figure 1. Milk yield according to cow's supplementation at peripartum and calf sex.

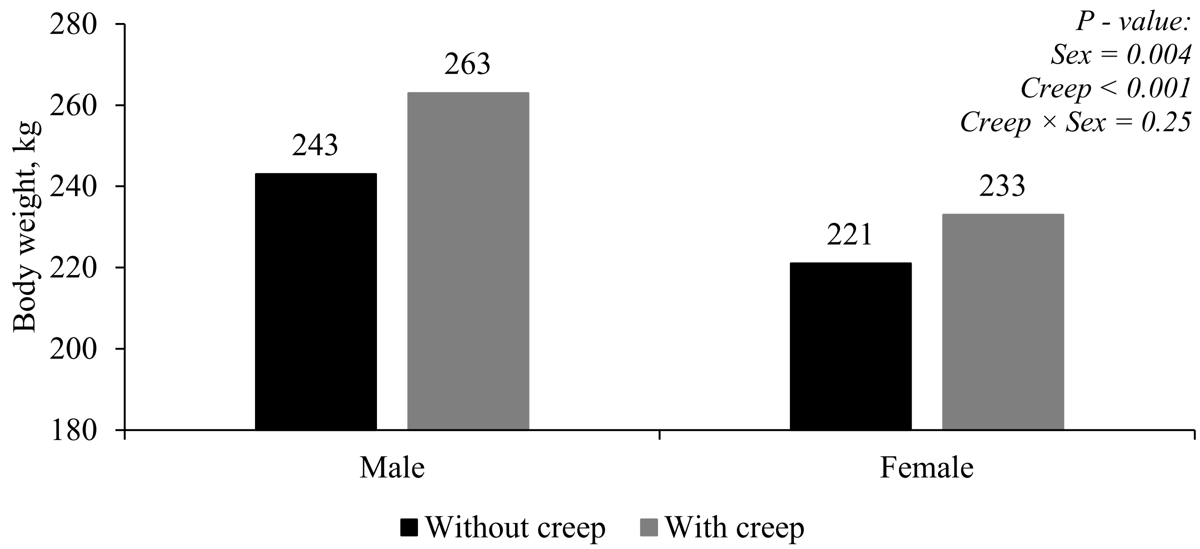

Figure 2. Effect of creep feeding supplementation on calves' body weight at weaning (7th month).

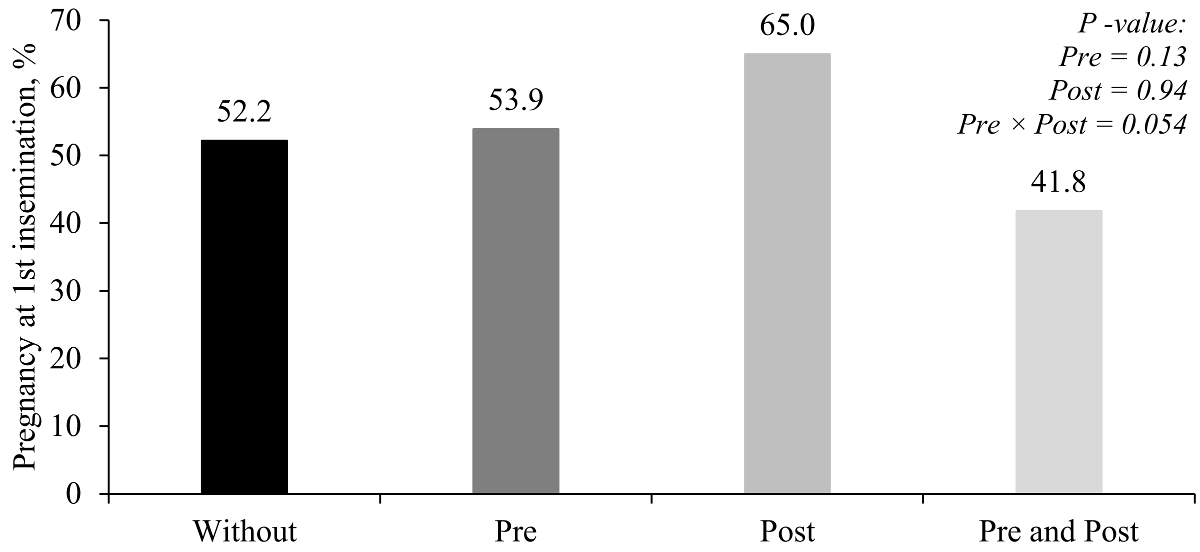

Figure 3. Pregnancy rate at first insemination according to cow's supplementation at peripartum.

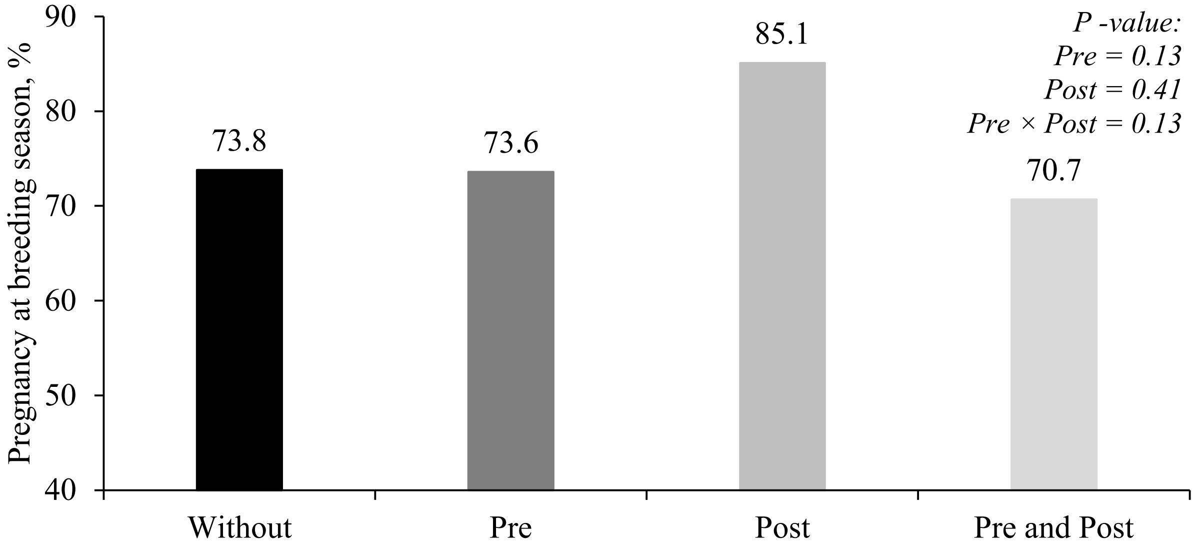

Figure 4. Pregnancy rate at breeding season according to cow's supplementation at peripartum.

Appendix

Appendix 1 – Cows

ABREU, L. M. DE B. **Suplementação de vacas de corte durante o pré-parto e desempenho produtivo de suas bezerras suplementadas em creep-feeding**. Dissertation (Master's dissertation in animal science)—Viçosa, Minas Gerais, Brasil: Universidade Federal de Viçosa, 5 jun. 2020.

ALBUQUERQUE, J. M. **Efeito da utilização de grãos secos de destilaria na suplementação de vacas de corte gestante à pasto**. Dissertation (Master's dissertation in animal science, in progress)—Viçosa, Minas Gerais, Brasil: Universidade Federal de Viçosa, In progress.

ALMEIDA, D. M. et al. Effects of pre- and postpartum supplementation on lactational and reproductive performance of grazing Nellore beef cows. **Animal Production Science**, v. 61, n. 2, p. 101–107, 22 out. 2020.

CALDERARO, L. V. et al. Effects of prepartum supplementation levels on the performance and metabolic responses of Nellore cows in a grazing system. **Semina: Ciências Agrárias**, v. 45, n. 3, p. 971–990, 13 jun. 2024.

DAVID, G. S. S. et al. Periparturient Changes in Voluntary Intake, Digestibility, and Performance of Grazing Zebu Beef Cows with or without Protein Supplementation. **Animals**, v. 14, n. 11, p. 1710, 6 jun. 2024.

FERREIRA, M. F. L. et al. Performance, metabolic and hormonal responses of grazing Nellore cows to an energy-protein supplementation during the pre-partum phase. **BMC veterinary research**, v. 16, n. 1, p. 108, 9 abr. 2020.

FERREIRA, M. F. L. et al. Effects of parity order on performance, metabolic, and hormonal parameters of grazing beef cows during pre-calving and lactation periods. **BMC Veterinary Research**, v. 17, n. 1, p. 311, 25 set. 2021.

GARCÉS-CARDENAS, J. E. **Nutritional and metabolic evaluation of nellore cows supplemented or not during the peripartum**. Thesis (Doctorate in Animal Science)—Viçosa, Minas Gerais, Brasil: Universidade Federal de Viçosa, 20 fev. 2017.

GONÇALVES, J. C. C. **Supplementary strategies for beef cows during the peripartum period in tropical conditions**. Dissertation (Master's dissertation in animal science, in progress)—Viçosa, Minas Gerais, Brasil: Universidade Federal de Viçosa, In progress.

LOPES, S. A. et al. Evaluation of grazing beef cows receiving supplements with different protein contents. **Semina: Ciências Agrárias**, v. 37, n. 5, p. 3361–3372, 26 out. 2016.

MORENO, D. S. et al. Pre-and postpartum supplementation strategies on the performance and metabolic status of grazing beef cows. **Pesquisa Agropecuária Brasileira**, v. 58, p. 3102, 26 jun. 2023a.

SANTOS, M. E. P. **Efeitos da suplementação pré-parto sobre o desempenho produtivo, reprodutivo e perfil metabólico de vacas Nelore em pastejo**. Dissertation (Master's dissertation in animal science)—Viçosa, Minas Gerais, Brasil: Universidade Federal de Viçosa, 16 mar. 2021.

SARAIVA, D. T. et al. Performance and Metabolic Responses of Nellore Cows Subjected to Different Supplementation Plans during Prepartum. **Animals**, v. 14, n. 16, p. 2283, jan. 2024.

SILVA, A. G. et al. Energetic-protein supplementation in the last 60 days of gestation improves performance of beef cows grazing tropical pastures. **Journal of Animal Science and Biotechnology**, v. 8, n. 1, p. 78, 2017a.

TRECE, A. S. **Avaliação nutricional e metabólica em vacas de corte suplementadas no pré e/ou pós-parto**. Dissertation (Master's dissertation in animal science)—Viçosa, Minas Gerais, Brasil: Universidade Federal de Viçosa, 31 jul. 2017.

Appendix 2 - Calves

ABREU, L. M. DE B. **Suplementação de vacas de corte durante o pré-parto e desempenho produtivo de suas bezerras suplementadas em creep-feeding**. Dissertation (Master's dissertation in animal science)—Viçosa, Minas Gerais, Brasil: Universidade Federal de Viçosa, 5 jun. 2020.

ALMEIDA, E. R. **Uso de grãos secos de destilaria na suplementação de bezerros de corte lactentes**. Dissertation (Master's dissertation in animal science, in progress)—Viçosa, Minas Gerais, Brasil: Universidade Federal de Viçosa, In progress.

CARVALHO, V. V. **Preweaning nutritional effects of supplements on performance of suckling beef calves grazing tropical pastures**. Thesis (Doctorate in Animal Science)—Viçosa, Minas Gerais, Brasil: Universidade Federal de Viçosa, 31 jul. 2018.

FERREIRA, M. F. L. et al. Effects of parity order on performance, metabolic, and hormonal parameters of grazing beef cows during pre-calving and lactation periods. **BMC Veterinary Research**, v. 17, n. 1, p. 311, 25 set. 2021.

LAGE, B. C. **Efeito da substituição parcial da proteína bruta do farelo de soja pela proteína bruta da ureia sobre o desempenho de Bezerros nelore lactentes.** Completion of higher education course work in Animal Science—Viçosa, Minas Gerais, Brasil: Universidade Federal de Viçosa, 2019.

LOPES, S. A. et al. Evaluation of supplementation plans for suckling beef calves managed on tropical pasture. **Semina: Ciências Agrárias**, v. 38, n. 2, p. 1027–1040, 2 maio 2017.

MARTINS, L. S. **Effects of supplementation on performance and nutritional and metabolic aspects of beef cows and calves at pasture**. Thesis (Doctorate in Animal Science)—Viçosa, Minas Gerais, Brasil: Universidade Federal de Viçosa, 22 fev. 2017.

MATOS, E. M. A. **Estimativa do consumo de matéria seca de vacas Nelore lactantes em pastagem**. Thesis (Doctorate in Animal Science, in progress)—Viçosa, Minas Gerais, Brasil: Universidade Federal de Viçosa, In progress.

MOREIRA, S. S. **Desempenho e respostas metabólicas de fêmeas Nelore em pastejo suplementadas nos períodos pré e pós-desmame**. Dissertation (Master’s dissertation in animal science)—Viçosa, Minas Gerais, Brasil: Universidade Federal de Viçosa, 17 ago. 2022.

MORENO, D. S. et al. Feeding strategies for rearing replacement beef heifers in a grazing system under tropical conditions. **Animal Feed Science and Technology**, v. 305, p. 115773, 1 nov. 2023b.

PAULA, C. et al. Effect of pre- and post-weaning supplementation on performance, nutritional, and metabolic characteristics in Nellore heifers under grazing. **Animal Production Science**, v. 62, n. 17, p. 1706–1719, 15 jul. 2022.

SARAIVA, D. T. **Effect of supplement levels on creep-feeding for suckling calves and prepartum Nellore cows on pasture**. Thesis (Doctorate in Animal Science). Universidade Federal de Viçosa, 28 fev. 2023.

SILVA, A. G. et al. Performance, endocrine, metabolic, and reproductive responses of Nellore heifers submitted to different supplementation levels pre- and post-weaning. **Tropical Animal Health and Production**, v. 49, n. 4, p. 707–715, 2017b.

SILVA, Á. E. M. **Farelo de trigo e ureia em suplementos para bezerros de corte lactentes em pastejo**. Dissertation (Master's dissertation in animal science)—Viçosa, Minas Gerais, Brasil: Universidade Federal de Viçosa, 16 jul. 2018.