Changes in nutritional characteristics and performance of grazing Nellore cows during the peripartum phase receiving or not protein supplementation

GABRIEL SANTOS SOUZA DAVID (g.david@unesp.br)
Universidade Estadual Paulista: Universidade Estadual Paulista Julio de Mesquita Filho
https://orcid.org/0000-0002-4003-5772

Éllem Maria de Almeida Matos
Universidade Federal de Vicosa

Bianca Rodrigues Domingos
Universidade Federal de Vicosa

Luiz Carlos Oliveira Sousa
Universidade Federal de Vicosa

Sidnei Antônio Lopes
Universidade Federal de Vicosa

Mario Fonseca Paulino
Universidade Federal de Vicosa

Sebastião de Campos Valadares Filho
Universidade Federal de Vicosa

Research Article

Keywords: Beef cattle, Gestation, Feed Intake, Lactation, Pasture

Posted Date: September 12th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1984266/v1

Abstract

We objective was to understand the changes in nutritional characteristics and performance of grazing Nellore cows during the peripartum receiving or not supplementation. Forty multiparous cows were used, divided into two treatments: CON - mineral mixture and SUP – protein supplementation. Digestibility trial was performed (-45,-30,-15, + 20, +40; days relative to calving). The average daily gain (ADG) pre and postpartum of the cows were measured and, in gestational and maternal tissues in the prepartum, in addition of body condition score (BCS). The calves were weighed at birth and at 30 days of age. There was an effect of treatment and period ($P \leq 0.10$) for dry matter, organic matter and crude protein intake, while forage intake was similar ($P \geq 0.10$), but with a period effect ($P \leq 0.10$). There was 14.37% decrease in dry matter intake from day − 30 to day − 15 of prepartum. In the postpartum period, at 20 days of lactation, there was increase of 72.66% in relation to the period − 15. There was interaction between period and treatment for all digestibilities ($P \leq 0.10$). No differences were observed in postpartum ADG ($P \geq 0.10$), BCS at calving and postpartum ($P \geq 0.10$). However, higher total ADG and in maternal tissues ($P \leq 0.10$) were observed on supplemented animals, but with ADG in gestational tissues similar ($P \geq 0.10$). It is concluded that there is a decrease in voluntary intake in grazing pregnant cows close to parturition and greater performance of animals supplemented in prepartum.

Introduction

The multiple supplements should be provided at specific moments when the utilization efficiency is maximized for beef cows. Several studies report that the final third of gestation is the phase which supplementation has the greatest impact on the productive success of cows (Diskin and Kenny., 2016; Mulliniks et al., 2016; Silva et al., 2017).

Due to the late gestation and early lactation (peripartum) are the period of greatest nutrient demands of beef cows (Gionbelli et al., 2016), knowledge of how the intake changes during this period makes become important. In general, there is a decrease in voluntary intake of beef cows close to calving (Forbes, 2007; Stanley et al., 1992), followed by increase after parturition (Linden et al., 2014). However, Ingvartsen et al. (1992), combining data from nine studies with pregnant cows, obtained inconsistent results, with values of intake at the end of pregnancy oscillating between an increase of 0.2%/week and a decrease of 9.4%/week.

Moreover, forage voluntary intake by grazing cattle may be affected by the use of protein supplementation (Detmann et al., 2014). Strauch et al. (2001) reported that beef heifers that received supplemental protein increased forage intake in the prepartum compared to heifers of control treatment. However, it is worth mentioning that the studies that included measurement the intake of beef cows (Gionbelli et al., 2016; Summers et al., 2015) in the peripartum were carried out in pens, with high inclusions of forage in the diet. In these situations, aspects peculiar to the pastoral environment are neglected.

We hypothesized that protein supplementation in the peripartum of grazing Nellore cows improve nutritional characteristics and performance these animals. In addition, there is a decrease in voluntary intake close to calving, but smaller for supplemented cows, and with increase after calving. We aimed was to evaluate the changes in nutritional characteristics and performance during the peripartum of Nellore cows under grazing, receiving or not protein supplementation.

Materials And Methods

Animal management, experimental design and treatments

The experiment was conducted at the Beef Cattle Farm of Animal Science Department of Universidade Federal de Vicosa, Viçosa, Minas Gerais, Brazil (20º45 'S and 42º52' W), between August and November during the dry season and the dry–wet transition seasons. The experimental area is located in a mountainous region (670 m altitude) with average annual precipitation of 1300 mm (Almeida et al., 2021). All practices involving the use of animals were approved by the Animal Care and Use Committee of the Universidade Federal de Viçosa, Brazi (Protocol no. 045/2021).

Forty multiparous Nellore cows were used, with initial weight of 525 ± 46 kg, body condition score (BCS) of 5.25 ± 0.85 at the beginning of the experiment, pregnant with F_1 Nellore x Red Angus males, from fixed-time artificial insemination (FTAI). Animals were randomly divided into eight paddocks with seven hectares each, evenly covered with *Urochloa decumbens grass*, with free access to water and feeders. The experimental design was completely randomized, with two treatments as following: *CON*- cows receiving only mineral mixture *ad libitum* during all the experimental period; *SUP*- cows receiving protein supplement (1 kg/d) during all the experimental period. The animals were rotated among the paddocks every 7 days, aiming to control the possible effects of paddocks on the treatments (pasture availability, water and trough location, relief, and others).

The supplement was a loose mesh formulated to contain 28% crude protein (CP) as supplied to meet approximately 24% of the CP maintenance requirements for a pregnant cow weighing 525 kg and expected calf birth weight (CBW) of 32 kg, according to the Nutrient Requirements of Zebu and Crossbred Cattle - BR-CORTE (Valadares Filho et al., 2016). Supplement was always provided at 11:00 am to minimize any interference of animal grazing behavior (Adams, 1985). The chemical composition of the supplement and pasture are available in Table 1.

Table 1
Chemical composition of the multipple supplement and of the *Urochloa decumbens* (hand-plucking)

Item	Supplement[4]	Forage (Days relative to calving)				
		-45	-30	-15	20	40
Dry matter[1]	890	450	453	370	273	301
Organic matter[2]	972	901	910	911	916	910
Crude protein[2]	288	48	50	72	102	92
NDFap[2]	86	696	674	643	553	548
iNDF[2]	9	253	262	247	169	171
NDIN[3]	23	229	233	304	363	384
NDIN = insoluble neutral detergent nitrogen						
[1]/ g/kg of natural matter						
[2]/ g/kg of dry matter						
[3]/ g/kg total nitrogen						
[4]/ soybean meal (100 g/kg), corn meal (760g/kg), urea (60 g/kg) e mineral mix (80 g/kg)						
Mineral mix - $CaHPO_4$ = 500g/kg; NaCl = 476.25 g/kg; $ZnSO_4$ = 15 g/kg Cu_2SO_4 = 7.5 g/kg $CoSO_4$ = 0.5g/kg; KIO_3 = 0.5g/kg and $MnSO_4$ = 0.25 g/kg						

Data collection

The BCS and weight of the cows were recorded at 45 days and 7 days before the estimated date of calving, on the day of calving and after 30 days of the calving, and the BCS performed by three trained observers using on a scale from 1 to 9 (NRC, 1996), always taking the weight of the cows at 08:00 am, except for the weights obtained at calving. The weights of calves at birth and at 30 days of age, as well as pregnancy rates of cows at the end of the breeding season, were also recorded. The average daily gain (ADG) in maternal and gestational tissues was calculated according with Gionbelli et al. (2015). During the breeding season the cows were synchronized and FTAI performed. Pregnancy diagnosis was conducted by transrectal ultrasonography.

The digestibility trials were performed to estimate intake and apparent digestibility during the pre and postpartum phases. Considering day 0 as the calving day, digestibility trials assessments were performed pre-calving at days − 45, -30 and − 15 before the expected calving date and on days + 20 and + 40 in milk.

Each trial lasted nine days, five of which were used only to adapt the animals to chromic oxide (Cr_2O_3) (Rosiere et al., 1980) and titanium dioxide (TiO_2) and 4 to collect of feces (Sampaio et al., 2011). The Cr_2O_3 was infused (packaged in paper) at 10:00 am directly into the animal's esophagus with the aid of a probe at a dose of 15 g per animal/d (Ribeiro et al., 2018), to estimation fecal output. The TiO2, in turn, was used to estimate individual supplement intake, being mixed daily with the supplement in the amount of 15 g per animal (Titgemeyer et al., 2001). The indigestible neutral detergent insoluble fiber (iNDF) was used as marker to estimate forage dry matter intake (Detmann et al., 2001). Starting on the sixth day of each trial, the feces collections were performed at the following times: 6:00 pm on the day 6, 2:00 pm on the day 7, 10:00 am on the day 8 and 6:00 am on the day 9. The samples were pooled to compose one sample per animal per period. The feces collection always coincided with the evaluated periods (-45; -30; -15; +20; +40).

On the last day each digestibility trial, hand-plucked sample of the forage was performed (De Vries, 1995) on each paddock separately, and these samples were used to estimate intake and apparent digestibility coefficients. Additionally, forage collections were carried out in each period to quantify the total availability of dry matter (DM) and potentially digestible dry matter (pdDM; Paulino et al., 2004) of the paddocks, being collected at ground level.

Laboratory analyzes and calculations

Samples of forage, supplement and feces were oven-dried at 60°C during 72 h (method G-001/2) and milled with a knife mill (Willey® TE-680) with sieves of 1 and 2 mm. The contents of dry matter (DM; dried for 16 hours at 105°C; INCT method-CA G-003/1), ash (complete combustion at 550ºC; method M-001/2) and CP (Kjeldahl method; INCT-CA method N-001/2) were evaluated according to the standard analytical procedures of the Brazilian National Institute of Science and Technology in Animal Science (INCT-CA, Detmann et al., 2021), using the samples at 1 mm. The content of NDF (neutral detergent fiber; using a heat-stable α-amylase) was evaluated according to the Barbosa et al. (2015), with correcting for contaminant ash and protein (NDFap; Licitra et al., 1996), also using the samples at 1 mm. The estimation of iNDF contents of the samples, processed to pass through a 2-mm screen siev, was performed according to Valente et al. (2011), in a 288-h *in situ* incubation procedure. The chromium concentration in the feces samples was determined with atomic absorption spectrophotometry (GBC Avanta Σ, Scientific Equipment, Braeside, Victoria, Australia) using digestion techniques with nitric and perchloric acids, at the ratio of 3:1 v v^{-1}, in one-step digestion with sodium molybdate as catalyst (Rocha et al., 2015). The concentration of titanium dioxide in the fecal samples was determined by spectrophotometry (INCT-CA; method M-007/2).

The potentially digestible dry matter (pdDM) was estimated according to Paulino et al. (2004), following the equation:

$$pdDM = 0{,}98 * (100 - NDF) + (NDF - iNDF)$$

where 0.98 is the true digestibility coefficient of cell content; NDF is the forage content of neutral detergent fiber (%); and iNDF is the forage content of iNDF (%).

The fecal output was determined by dividing the amount of Cr_2O_3 infused by its concentration in the feces. The individual supplement intake (SI; kg/d) was determined through the ratio of TiO_2 in the feces to the concentration of the indicator in the supplement, as follows:

$$SI = \left[\frac{FOxCMf}{CMs}\right]$$

where FO is the fecal output (kg/d); CMf is the concentration of the marker in the feces (kg/kg); and CIS is the concentration of the marker in the supplement (kg/kg).

Voluntary intake of dry matter of forage (FDMI) was calculated from the following equation:

$$IDMF = \frac{[(FOx\mathrm{iNDFf}) - \mathrm{SI}x\mathrm{iNDFs}]}{\mathrm{iNDFfor}}$$

where FE = fecal output (kg/d), iNDFf is the concentration of iNDF in the feces (kg/kg), SI is the supplement DM intake (kg/d), iNDFs is the concentration of the iNDF in supplement (kg/kg), and iNDFfor is the concentration of the iNDF in forage (kg/kg).

Statistical analysis

The data related to the performance of the cows were analyzed separately for the pre and postpartum phases. The variables that were evaluated over time in the same animals (i.e., intake and apparent digestibility) were performed as repeated measure (fixed effect; Kaps and Lamberson, 2004). The choice of the best structure of (co)variance matrix was based on Akaike's information criterion with correction. The degrees of freedom were estimated by the Kenward–Roger method. The initial body weight of the cows was used as covariate in the model when the effect of this variable on the productive and nutritional parameters of the animals and the birth weight of the calves was considered significant ($P \leq 0.10$). For nutritional characteristics, when appropriate, the command PDIFF-SAS (Pr > | t |) was used to examine the differences among treatment at each period for each dependent variable. The pregnancy rate was evaluated by chi-square test.

The analyzes were performed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC), and significances were declared at $P \leq 0.10$. In this type of experiments, animals are handled freely, hence subjected to several natural or unnatural influences, what strongly interfere to their social and intake behavior compared to feedlot experiments. Therefore, there is a higher probability of occurrence of type-II error (accept H0 when is false). The best control of the type II error is obtained by increasing the α value (i.e., 0.10 rather than 0.05) (Ferreira et al., 2020)

Results

Intake and apparent digestibility

The mean values of availability (kg/ha) and supply (g pdDM/ 100 kg of body weight) of the *Urochloa decumbens* forage were 3267.6 and 6.31, respectively.

Overall, the supplementation increased intake ($P \leq 0.10$; kg/day) of DM, OM (organic matter), CP and, DMO (digestible organic matter) (Table 1). The supplemented animals exhibited, on average, 9.13% more TDMI (total dry matter intake) compared to the control animals. However, there was no influence of supplementation ($P \geq 0.10$) on the intake of forage dry matter, NDFap and, iNDF, with means of 9.52; 5.76 and 1.96 kg, respectively.

There was a period effect (i.e., days relative to calving) ($P \leq 0.10$) for all intakes variables (Table 2) and no period and treatment interaction effect ($P \geq 0.10$) for any of these variables. Decreases ($P \leq 0.10$) of 14.37 and 14.23% were observed from the period − 30 to -15 for DM intake and forage intake, respectively (Fig. 1). On the other hand, there were increases of 72.6 and 77.5% from − 15 to + 20 for DM intake and forage intake, respectively (Fig. 1). The intake of OM and DOM followed the behavior of TDMI, with lower intake of these variables close to parturition (-15), intermediate values in the periods − 45 and − 30 and higher values in the postpartum period, no difference between both (+ 20 and + 40).

Table 2
Effects of protein supplementation on voluntary intake of grazing beef cows during peripartum period.

Item	Treatments		SEM	*P-value*		
	CON	SUP		S	Period (P)	S x P
Intake (kg/d)						
Dry matter	9.53	10.40	0.280	0.044	< 0.0001	0.96
Forage DM	9,53	9.50	0.277	0.93	< 0.0001	0.91
Organic matter	8.69	9.50	0.258	0.039	< 0.0001	0.99
DOM	3.90	4.69	0.149	0.002	< 0.0001	0.95
Crude protein	0.72	0.93	0.023	< 0.0001	< 0.0001	0.16
NDFap	5.81	5.71	0.149	0.67	< 0.0001	0.94
Indigestible NDF	1.97	1.95	0.050	0.80	< 0.0001	0.64
Intake, g/kg BW						
Dry matter	19.0	20.4	0.054	0.10	< 0.0001	0.91
Forage DM	19.1	18.6	0.052	0.55	< 0.0001	0.78
Crude protein	17.3	18.6	0.050	0.079	< 0.0001	0.96
NDFap	11.5	11.1	0.028	0.33	< 0.0001	0.96
Indigestible NDF	3.88	3.83	0.011	0.76	0.0002	0.49

SEM = standard error of the mean

BW = body weight

DM = dry matter

DOM = dietary content of digested organic matter.

NDFap = neutral detergent fiber corrected for contaminant ash and protein

S = effect of supplementation; S x P = interaction between supplementation and period.

The CP intake remained the same throughout the prepartum period ($P \geq 0.10$), with an increase in the + 20 period of approximately 122% in relation to the prepartum period, but with an intermediate value for the + 40 period ($P \leq 0.10$). There was a 19% decrease in NDFap intake from the − 30 to -15 period, with higher intake after calving ($P \leq 0.10$; +20). However, for iNDF intake, lower values of this variable are observed for the postpartum period, but with lower intake at -15 ($P \leq 0.10$). Furthermore, smaller variations were observed in the consumption of iNDF compared to NDFap intake.

An interaction between treatment and period was detected (P ≤ 0.10) for the digestibilities of OM, NDFap and CP (Table 3). We observed differences in OM digestibility among the treatments during − 30 and + 40 (Fig. 2) (P ≤ 0.10), but with similar values of this variable in the other periods (P ≥ 0.10). For NDFap digestibility, there was a higher variability in animals supplemented only during + 40 period (Fig. 3). On the other hand, higher CP digestibility values (P ≤ 0.10) were verified for the animals supplemented throughout in the prepartum phase (Fig. 4), but with similar values in the postpartum (P ≥ 0.10).

Table 3
Effects of protein supplementation on voluntary intake of grazing beef cows during peripartum period.

Item	Treatments		SEM	*P-value*		
	CON	SUP		S	Period (P)	S x P
g/kg BW						
Organic matter	430	451	0.811	0.090	< 0.0001	0.066
NDFap	495	500	0.763	0.648	< 0.0001	0.098
Crude protein	160	334	1.579	< 0.0001	< 0.0001	< 0.0001
SEM = standard error of the mean						
BW = body weight						
NDFap = neutral detergent fiber corrected for contaminant ash and protein						
S = effect of supplementation; S x P = interaction between supplementation and period.						

Performance

Supplementation increased (P ≤ 0.10) total ADG and in maternal tissues in the peripartum phase, but there was no difference (P ≥ 0.10) for ADG of gestational tissues (Fig. 5), as well as for BSC at calving and postpartum, postpartum ADG, pregnancy rate, and birth and 30-day weight of calves (Table 4).

Table 4
Effects of protein supplementation on performance of grazing beef cows during peripartum period.

Item	Treatments		SEM	P-value
	CON	SUP		
Postpartum ADG	-0.114	-0.133	0.1459	0.928
Calving BCS	5.37	5.11	0.115	0.131
Postpartum BCS	4.87	4.96	0.163	0.474
Calf birth weight	32.5	34.4	0.871	0.124
CBW30	69.8	72.3	2.530	0.469
Pregnancy rate (%)	80	73.7	-	0.639
CBW Calf Birth Weight at 30-d				
SEM = standard error of the mean				

Discussion

The forage resource accessible to grazing must be interpreted through a perspective of fraction potentially convertible into animal product. From this perspective, the pdDM constitutes an integrative measure of the quanti-qualitative conditions of pasture, since that defines simultaneously characteristics related to the forage mass and its nutritional variables. At least 4 to 5 kg of pdDM/100 kg body weight should be guaranteed to allow selective grazing by the animals and, therefore, not affect voluntary intake and productive performance (Paulino et al., 2004). It should be noted that in all experimental periods, the values of forage pdDM supply were within the recommended values.

In this study, all animals showed weight loss of maternal tissues during the final third of pregnancy. In fact, there is a pattern of transition from anabolic state to catabolic state in pregnant cows, on average, starting at 240 days of gestation (Scheaffer et al., 2001; Meyer et al., 2010; Moreira, 2020). In parallel, limited availability of CP has been associated with decreased animal performance (Leng, 1990; Paulino et al., 2008). The average content of 57 g CP/kg DM of forage in the pre-calving period affected the growth of rumen microorganisms, being below the minimum necessary value (70 g CP/kg DM) to maintain their basal growth (Lazzarini et al., 2009). In these circumstances, as occurred in this study, there is body mobilization, notably in nitrogen compounds, to support the placental demands and the mass of nitrogen recycled to the rumen (Rufino et al., 2016; McNeill et al., 1997; Lopes et al., 2020).

However, supplementation decreased mobilization of body reserves of animals (i.e., less weight loss of maternal tissues) and greater total ADG. From this perspective, we understand that protein supplementation in the pre-calving period of grazing Nellore females should be explored based on its interactive effects with the basal forage resource, maximizing animal performance (Paulino et al., 2008).

Several studies conducted in tropical regions have also verified the benefits of protein supplementation for grazing pregnant females on productive performance (Lopes et al., 2016; Moura et al., 2020; Ferreira et al., 2020).

Barcelos et al. (2022) shows that there is an associative effect between the supply of energy and protein to the cow in the prepartum and the CBW. However, in this work, the supplementation did not affect CBW, which is corroborated by gestation tissues ADG similar. This condition suggests a compensatory mechanism for cows without supplementation that, even under unfavorable conditions, modulates nutrient partition in favor of fetal growth (Wood et al., 2013). In growing animals, the rumen is the priority, therefore, only after supplying the N needs in the rumen is the supplementary N destined for anabolic functions (Batista et al., 2016). On the other hand, in pregnant cows the priority destination of available N seems to reside in the gestational tissues (Bell and Ehrhardt, 2000; Lopes et al., 2020).

The initial period of lactation is critical, since from 3 to 6 weeks the lactation peak occurs in Nellore cows on pasture (Ferreira et al., 2021), with numerous metabolic, physiological, and hormonal changes occurring in an integrated way to support the new demands of nutrients needed for milk synthesis (Bauman and Currie, 1980). Despite the increase in forage intake observed after calving, lactating beef cows rarely present a nutrient intake consistent with their demands, resulting in frequent loss of body weight, as observed in this study (Jordan et al., 1973; Linden et al., 2014).

Studies in tropical conditions indicate that the productive response of grazing cattle to protein supplementation is inversely related to the nutritional value of the forage (Almeida et al., 2022; Sousa et al., 2022). In association, there is a lot of evidence that supplementation of beef cows in the prepartum period, which coincides with the dry season, is more important than in the postpartum period, and this response is attributed to the physiological conditions inherent to the phase (Hess et al., 2005; Diskin and Kenny., 2016). In fact, the results of this study point to a greater importance of protein supplementation in the prepartum compared to the postpartum period since the supplementation promoted an increase in the productive performance of the cows at the end of pregnancy. On the other hand, during the postpartum period there was no difference in the productive performance of the animals. In beef cattle to achieve greater profitability, multiple supplements should be provided at specific times when maximum efficiency of supplement utilization is achieved by beef cows (Mulliniks et al., 2016).

The evaluation of BCS in the last third of pregnancy, at calving and after calving, a practical and low-cost method, being essential in order to estimate the body energy reserves in beef cows and predict the reproductive success (Ayres et al., 2014; Vedovatto et al., 2022). It is noteworthy that the animals of both treatments had an average body condition (5) suitable for parturition (NRC, 2000), due to the good availability of forage. Thus, no differences were expected in the BCS and, therefore, in the pregnancy rate. Corroborating the results, Bohnert et al., 2013, working with beef cows with high and low BCS, concluded that this measure has a positive relationship with the pregnancy rate. The BCS of SUP and CON cows were similar, which is in accordance with previous studies where late gestation cows consuming low-quality forage and were supplemented (Ferreira et al., 2020; Lopes et al., 2020).

The supply of rumen nitrogen is understood as a decisive factor to optimize the digestion of fibrous compounds in the rumen and increase forage intake (Lee et al., 1987; DelCurto et al., 2000; Souza et al., 2010). Additionally, maximizing forage voluntary intake is also related to some post-digestive effects, with metabolic adequacy of absorbed nutrients (Leng, 1990). Detmann et al. (2014b), in a meta-analytic approach, suggested that the maximum responses to protein supplementation on forage intake and fiber digestibility are achieved at dietary CP levels in the order of 145 g CP/kg DM and 99 g CP/kg MS, respectively. Thus, increases in forage intake and fiber digestibility of animals were expected with supplementation. However, similarly to the results obtained in the present study, with the exception of fiber digestibility in the + 40 period, studies with grazing Nellore females commonly do not demonstrate additive associative effects of supplementation on forage intake and fiber digestibility (Silva et al., 2017; Moura et al., 2020). In fact, the effects of protein supplementation seem to be more evident regarding the productive performance of the animals (Sousa et al., 2022).

The higher total dry matter intake for the supplemented animals is explained exclusively by the supplement intake since there was no difference for forage intake. Furthermore, the higher intakes of organic matter and digestible organic matter in these animals are explained by the higher intakes of total dry matter and the higher digestibility of organic matter in the supplement. The similar intake of NDFap among treatments reflects the absence of difference between the consumption of forage dry matter since the pasture represents most of the dietary fiber. The higher CP intake for the supplemented animals was due to the additional protein of the supplement.

As expected, the intake of OM, DMO and NDFap followed the variations observed in forage intake. In contrast, variations in CP intake did not follow forage intake, as the highest CP content in forage prepartum was verified during the period of lowest intake (-15), which justifies the similarity in CP intake by the animals throughout the prepartum period. Thus, the difference among periods for the CP intake basically implies of the differences in the TDM intake and the CP content of the forage. The increase in apparent digestibility of organic matter for animals supplemented at + 40 is associated with higher NDFap digestibility in this period. On the other hand, CP digestibility in the initial periods was different between the treatments (except for + 20), with lower CP digestibility for animals in the control treatment. This result was expected, since the supplemented animals had a higher intake of CP, which increases its participation in the total diet, reducing the relative participation of the metabolic fecal fraction (Van Soest, 1994).

Contrary to our initial hypothesis, supplementation was not able to change the intake pattern of the animals throughout the peripartum. Weston (1982) reported that pregnant cows fed high-concentrate diets also exhibited decreased pre-calving intake. Thus, it is understood that the physiological effects inherent to pregnancy on intake outweigh the improvements resulting from supplementation. It should be noted that as there was no effect of the interaction between period and treatment for dry matter intake, other practical approaches to supplementation in the peripartum of grazing beef cows are necessary (e.g., mass, nutritional value, and ingredients of multiple supplement).

Meta-analytical assessments in the tropics (Detmann et al., 2014a; Fernandes et al., 2022) show that pasture qualitative characteristics, notably CP and iNDF, are associated with forage intake by animals on pasture. The reduction observed in the dry matter intake and forage intake at -15 period, even with an improvement in the nutritional value of the pasture, in terms of iNDF and CP, supports the hypothesis that pregnancy regulates voluntary intake of beef cows (Forbes, 2007). On the other hand, after calving (+ 20) there was an improvement in forage quality, with a simultaneous increase in the intake of total dry matter and forage. These results agree with a series of previous studies that reported a reduction in voluntary intake at the end of pregnancy in beef cows and an increase in intake after calving, which is related to the increased energy demand for milk synthesis and the lack of compression of the gravid uterus on the rumen (Moreira, 2020; Ovenell et al., 1991; Marston and Lusby, 1995).

In fact, Forbes (1968) reported rumen capacity is reduced due to increased uterine volume during late gestation. The prediction of the reduction of intake at the end of pregnancy can bring a more strategic approach to the supplementation technique. The increasing nutrient density in late gestation diets to meet protein requirements is critical and the decrease in maternal tissue loss confirms this statement.

The ruminants in milk have higher intake compared to non-lactating animals. As in this study, differences of up to 100% were observed for sheep and cattle (ARC, 1980; Adenuga et al., 1990). However, some authors (Aguiar, 2019; Kessel et al., 2008) suggest that during the first week of lactation, there is still a limitation in the intake capacity of cows, since during this period the rumen is still returning to its normal volume, with an increase in intake from this stage onwards.

Regardless of protein supplementation, grazing Nellore cows decrease voluntary forage intake close to calving, with subsequent increase after calving. The protein supplementation does not impact the performance of grazing Nellore cows during the early lactation period. However, supplementation increases the productive performance during prepartum of grazing beef cows, notably, in terms of maternal tissue gains.

Declarations

Acknowledgements

The authors would like to thank the Universidade Federal de Viçosa (UFV) for providing the necessary structure to carry out this research.

Authors' contributions

G.S.S. David. led the research, writing the original draft and formal analysis. E. M. A. Matos participated of performing the experiment and data collection. B. R. Domingos participated of performing the experiment and data collection. L.C.O de Sousa participated of performing the experiment, data collection and formal analysis. S. A. Lopes participated of performing the experiment, the project administration, and the critical review. M. F. Paulino participated of project administration, and the critical review.

S.C.Valadares Filho participated of conceptualization, methodology, the project administration, and the critical review.

Conflict of interest statement

The authors confirm that there are no conflicts of interest.

Ethics approval

The research carried out in accordance with the Animal Care and Use Committee of the Universidade Federal de Viçosa, Brazil (protocol CEUAP-UFV 045/2021).

References

1. Adams, D.C., 1985. Effect of time of supplementation on performance, forage intake and grazing behavior of yearling beef steers grazing Russian wild ryegrass in the fall. Journal of Animal Science, 61, 1037–1042.
2. Almeida, D.M., Marcondes, M.I., Rennó, L.N., Martins, L.S., Marquez, D.E.C., Saldarriaga, F.V., Villadiego, F.A.C., Ortega, R.M., Moreno, D.P.S., Moura, F.H., Cunha, C.S. and Paulino, M.F., 2021. Effects of pre- and postpartum supplementation on lactational and reproductive performance of grazing Nellore beef cows. Animal Production Science, 61, 101-107. doi: 10.1071/AN18251.
3. Almeida, D.M., Silva, A.L., Paulino, M.F., Silva, T.E., Detmann, E., and Marcondes, M.I. 2022. Performance of *Bos indicus* beef cattle supplemented with mineral or with concentrates in tropical *Urochloa decumbens* pastures: A meta-regression approach. Animal Feed Science and Technology, 283, doi: 10.1071.
4. Ayres, H., Ferreira, R.M., Torres-Júnior, J.R.S., Demétrio, C.G.B., Sá Filho, M.F., Gimenes, L.U., Penteado, L., D’Occhio, M.J., and Baruselli, P.S. 2014. Inferences of body energy reserves on conception rate of suckled Zebu beef cows subjected to timed artificial insemination followed by natural mating. Theriogenology, 82, 529–536.
5. Barbosa, M.M., Detmann, E., Rocha, G.C., Franco, M.O., and Valadares Filho, S.C. 2015. Evaluation of Laboratory Procedures to Quantify the Neutral Detergent Fiber Content in Forage, Concentrate, and Ruminant Feces, Journal of AOAC INTERNATIONAL, 98, 883–889.
6. Barcelos, S.S; Nascimento, K.B.; Silva, T.E.; Mezzomo, R.; Alves, K.S.; Duarte, M.S.; and Gionbelli, M.P. 2022. The Effects of Prenatal Diet on Calf Performance and Perspectives for Fetal Programming Studies: A Meta-Analytical Investigation. Animals, 12, doi.org/10.3390/ani12162145
7. Batista, E.D., Detmann, E., Titgemeyer, E.C., Valadares Filho, S.C., Valadares, R.F.D., Prates, L.L., Rennó, L.N., and Paulino, M.F.2016. Effects of varying ruminally undegradable protein supplementation on forage digestion, nitrogen metabolism, and urea kinetics in Nellore cattle fed low-quality tropical forage. Journal of Animal Science, 94, 201–216.

8. Bauman, D. E.; Currie, W. B.1980. Partitioning of nutrients during pregnancy and lactation: a review of mechanisms involving homeostasis and homeorhesis. Journal of Dairy Science, 63, 1514-1529.
9. Bell, A.W., Ehrhardt, R.A. 2000. Regulation of macronutrient partitioning between maternal and conceptus tissues in the pregnant ruminant. In Ruminant physiology: digestion, metabolism, growth and reproduction (ed. Pb Cronjé), pp. 275–293. CABI Publishing, New York, NY, USA.
10. De Vries, M. 1995. Estimating forage intake and quality in grazing cattle: a reconsideration of the hand-plucking method. Journal Range Management. 48, 370–375. https://doi.org/10.2307/4002491
11. DelCurto, T., Hess, B.W., Huston, J.E., Olson, K.C. 2000. Optimum supplementation strategies for beef cattle consuming low-quality roughages in the western United States. Journal of Animal Science, 77, 1–16.
12. Detmann, E., Costa e Silva, L.F., Rocha, G.C., Palma, M.N.N., Rodrigues, J.P.P. 2021. Métodos para análise de alimentos. MG, Brasil: Suprema, Visconde do Rio Branco.
13. Detmann, E., Gionbelli, M.P., and Huhtanen, P. 2014a. A meta-analytical evaluation of the regulation of voluntary intake in cattle fed tropical forage-based diets. Journal of Animal Science. 92, 4632-4641.
14. Detmann, E., Paulino, M.F., Zervoudakis, J.T., Valadares Filho, S.C., Euclydes, R.F., Lana, R.P., and Queiroz, D.S. 2001. Chromium and internal markers in intake determination by crossbred steers, supplemented at pasture. Revista Brasileira de Zootecnia. 30, 1600–1609.
15. Detmann, E., Valente, E.E.L., Batista, E.D., and Huhtanen, P. 2014b. An evaluation of performance and efficiency of nitrogen utilization in cattle feed tropical grass pastures with supplementation. Livestock Science. 162, 141–53.
16. Diskin, M.G., Kenny, D.A. 2016. Managing the reproductive performance of beef cows. Theriogenology.86, 379–87.
17. Fernandes, G. A., Oliveira, A.S., Araújo, C.V., Couto, V.R.M., Moraes, K.A.K., and Moraes, E.H.B.K. 2022. Prediction of pasture intake by beef cattle in tropical conditions. Tropical Animal Health and Prodiction, 1:54, doi: 10.1007/s11250-021-03018-1.
18. Ferreira, M.F.L., Rennó, L.N., Detmann, E., Paulino, M.F., Valadares Filho, S.C., Moreira, S.S., Martins, H.C., Oliveira, B.I.C., Marquez, J.A., and Cidrine, I.P. 2020. Performance, metabolic and hormonal responses of grazing Nellore cows to an energy-protein supplementation during the pre-partum phase. BMC Veterinary Research, 16:108.
19. Ferreira, M.F.L., Rennó, L.N., Rodrigues, I.I., Valadares Filho, S.C., Costa e Silva, L.F., Silva, F.F.E., Detmann, E., and Paulino, M.F. 2021. Evaluation of non-linear models to predict potential milk yield of beef cows according to parity order under grazing. Frontiers in Veterinary Science, 8, https://doi.org/10.3389/fvets.2021.721792.
20. Forbes, J. M. 2007. Voluntary Food Intake and Diet Selection in Farm Animals. 2nd.ed. Wallingford, UK:CABI Publishing.
21. Forbes, J.M. 1968. The physical relationships of the abdominal organs in the pregnant ewe. Journal of Agricultural Science, 72:119–121. doi:10.1017/S0021859600020475

22. Gionbelli, M.P., Duarte, M.S., Valadares Filho, S.C., Detmann, E., Chizzotti, M.L., Rodrigues, F.C., Zanetti, D., Gionbelli, T.R.S., and Machado, M.G. 2015. Achieving body weight adjustments for feeding status and pregnant or non-pregnant condition in beef cows. Plos One, 10(3), e0112111. https://doi.org/10.1371/journal.pone.0112111
23. Gionbelli, M.P., Valadares Filho, S.C., Duarte, M.S. 2016. Exigências nutricionais para vacas de corte vazias e gestante, em: Valadares Filho, S.C. *et al*. (Eds.), Exigências Nutricionais de Zebuínos Puros e Cruzados - BR-CORTE 3.0. Suprema, Viçosa, Brasil, p. 251-272.
24. Hess, B.W., Lake, S.L., and Scholljegerdes, E.J. 2005. Nutritional controls of beef cow reproduction. Journal of Anim Science.83:90–106.
25. Ingvartsen, K.L., Andersen, H.R, ad Foldager, J. 1992. Effect of sex and pregnancy on feed intake capacity of growing cattle. Acta Agriculturae Scandinavica, Animal Science 42, 40–46.
26. Jordan, W. A., Lister, E. E., Wauthy, J. M., and Comeau, J.E. 1973. Voluntary roughage intake by nonpregnant and pregnant or lactating beef cows. Canadian Journal of Animal Science 53, 733–738.
27. Kaps, A.M., Lamberson, W.R. Biostatistics for animal science. London: CABI Publishing, 2004. 445p
28. Lazzarini, I., Detmann, E., Sampaio, C.B. Paulino, M.F., Valadares Filho, S.C., Souza, M.A., and Oliveira, F.A. 2009. Intake and digestibility in cattle fed low-quality tropical forage and supplemented with nitrogenous compounds. Revista Brasileira Zootecnia. 38, 2021–2030.
29. Lee, G., Hennessy, D.W., Nolan, J., Leng, R.A. 1987. Responses to nitrogen and maize supplements by young cattle offered a low-quality pasture hay. Australian Journal of Agricultural Research. 38, 195–207.
30. Leng, R.A. 1990. Factors affecting the utilization of ‘poor-quality’ forages by ruminants particularly under tropical conditions. Nutrition Research Reviews. 3, 277–303.
31. Licitra, G., Hernandez, T.M., and Van Soest, P.J. 1996. Standartization of procedures for nitrogen fractionation of ruminant feeds. Animal Feed Science Technology, 57, 347–358.
32. Linden, D.R., Tigemeyer, E.C., Olson, K.C., and Anderson, D.E. 2014. Effects of gestation and lactation on forage intake, digestion, and passage rates of primiparous beef heifers and multiparous beef cows. Journal of Animal Science, 92, 2141-2151.
33. Lopes, R.C., Sampaio, C.B., Trece, A.S., Teixeira, P.D., Gionbelli, T.R.S., Santos, L.R., Cosra, T.C., Duarte, M.S., and Gionbelli, M.P. 2020. Impacts of protein supplementation during late gestation of beef cows on maternal skeletal muscle and liver tissues metabolism. Animal 14, 1867-1875.
34. Lopes, S.A., Paulino, M.F., Detmann, E. Rennó, L.N., Valente, E.E.L., Cabral, C.H.A., Carvalho, V.V., Lima, J.A.C., Manso, M.R., and Bonfá, H.C. 2016. Evaluation of grazing beef cows receiving supplements with different protein contents. Semina: Ciências Agrárias. 37:3361–3372.
35. Marsh, R., Curran, M. K., Campling, R. C. 1971. The voluntary intake of roughages by pregnant and by lactating dairy cows. Animal Production, 13, 107-116 doi:10.1017/S0003356100029482.
36. Marston, T. T.; Lusby, K. S. 1995. Effects of energy or protein supplements and stage of production on intake and digestibility of hay by beef cows. Journal of Animal Science, 73, 651-6.

37. McNeill, D.M., Slepetis, R., Ehrhardt, R.A., Smith, D.M., and Bell, A.W. 1997. Protein Requirements of sheep in late pregnancy: partitioning of nitrogen between gravid uterus and maternal tissues. Journal of Animal Science 75, 809–816.
38. Meyer, A.M., Reed, J.J., Vonnahme, K.A., Soto-Navarro, S.A., Reynolds, L.P., Ford, S.P., Hess, B.W., and Caton, J.S. 2010. Effects of stage of gestation and nutrient restriction during early to mid-gestation on maternal and fetal visceral organ mass and indices of jejunal growth and vascularity in beef cows. Journal of Animal Science. 88, 2410-2424.
39. Moreira, G.M., 2020. Effects of pregnancy on quantitative aspects of nutrition, physiology and metabolism of beef heifers (PhD Thesis). Universidade Federal de Lavras, MG, Brazil.
40. Moura, F.H., Costa, T.C., Trece, A.S., Melo, L.P., Manso, M.R., Paulino, M.F., Rennó, L.N., Fonseca, M.A., Detmann, E., Gionbelli, M.P., and Duarte, M.S. 2020. Efects of energy-protein supplementation frequency on performance of primiparous grazing beef cows during pre and postpartum, Asian-Australasian Journal of Animal Sciences, 33, 1430-1443.
41. Mulliniks, J.T., Sawyer, J.E., Waterman, R.C., and Petersen, M.K. 2016. Delaying postpartum supplementation in cows consuming low-quality forage does not alter cow and calf productivity. Agricultural Sciences. 7, 642- 649.
42. National Research Council – NRC. Nutrient requeriments of beef cattle. 7 ed. Whashington, D.C.: National Academic Press, 1996. 242p.
43. National Research Council – NRC, 2000. Nutrient requirements of beef cattle. 7th edition, National Academies Press, Washington D. C.
44. Ovenell, K., Lusby, K.S., Horn, G.W., and McNew, R.W. 1991. Effects of lactational status on forage intake, digestibility, and particulate passage rate of beef cows supplemented with soybean meal, wheat middlings, and corn and soybean meal. Journal of Animal Science, 69, 2617-2623.
45. Paulino, M.F., Detmann, E., Valadares Filho, S.C. Nutrição de bovinos em pastejo. In: SIMPÓSIO SOBRE MANEJO ESTRATÉGICO DA PASTAGEM, 4, 2008, Viçosa. Anais... Viçosa: DZO-UFV, 2008. p.131-169
46. Paulino, M.F.; Figueiredo, D.M.; Moraes, E.H.B.K., Porto, M.O., Sales, M.F.L., Acedo, T.S., Villela, S.D.J., Valadares Filho, S.C. Suplementação de bovinos em pastagens: uma visão sistêmica. In: SIMPÓSIO INTERNACIONAL DE PRODUÇÃO DE GADO DE CORTE, 4., 2004, Viçosa, MG. Anais… Viçosa, MG: DZO - UFV, 2004. p. 93-139.
47. Ribeiro, C.B., Oliveira, L.O.F., Morais, M.G., Fernandes, H.J., Carneiro, M.M.Y., Rocha, R.F.A.T., and Rocha, D.T. Kaolin and chromic oxide under different forms of administration in a study of consumption and digestibility. Semina: Ciências Agrárias. 39, 2609-2622.
48. Rocha, G.C., Palma, M.N.N., Detmann, E., and Valadares Filho, S.C. 2015. Evaluation of acid digestion techniques to estimate chromium contents in cattle feces. Pesquisa Agropecuária Brasileira, 50(1), 92-95. https://doi.org/10.1590/S0100-204X2015000100010
49. Rosiere, R.E., Galyen, M.L., and Wallace, J.D. 1980. Accuracy of roughage intake estimations as determined by a chromic oxide – in vitro digestibility technique. Journal Range Management. 33,

237– 239.

50. Rufino, L.M.A., Detmann, E., Gomes, D.I., Reis, W.L.S., Batista, E.D., Valadares Filho, S.C., and Paulino, M.F., 2016. Intake, digestibility, and nitrogen utilization in cattle fed tropical forage and supplemented with protein in the rumen, abomasum, or both. Journal of Animal Science and Biotechnology. 7, 11. https://doi.org/10.1186/s40104-016-0069- 9.
51. Sampaio, C. B., E. Detmann, T. N. P., Valente, V. A. C., Costa, V.A.C., Valadares Filho, S.C., and Queiroz, A.C. 2011. Fecal excretion patterns and short term bias of internal and external markers in a digestion assay with cattle. Revista Brasileira de Zootecnia, 40, 657—665.
52. Scheaffer, A.N., Reynolds, L.P. 2001. Influence of pregnancy on body weight, ruminal characteristics, and visceral organ mass in beef heifers. Journal of Animal Science, 79, 2481-2490.
53. Silva, A. G., Paulino, M.F., Detmann, E., Fernandes, H.J, Silva Amorim, L., Ortega, R.E.M., Carvalho, V.V., Costa Lima, J.A., Moura, F.H., Monteiro, M.B., and Bitencourt, J.A. 2017. Energetic-protein supplementation in the last 60 days of gestation improves performance of beef cows grazing tropical pastures. Journal of Animal Science and Biotechnology 8, 7 8.
54. Sousa, L.C.O., Palma, M.N.N., Franco, M.O., Detmann, E. 2022. Does frequency of protein supplementation affect performance of cattle under grazing in tropical pastures? Animal Feed Science and Technology. 289. 2022. https://doi.org/10.1016/j.anifeedsci.2022.115316
55. Souza, M.A., Detmann, E., Paulino, M.F., Sampaio, C.B., Lazzarini, I., and Valadares Filho, S.C. 2010. Intake, digestibility, and rumen dynamics of neutral detergent fibre in cattle fed low-quality tropical forage and supplemented with nitrogen and/or starch. Tropical Animal Health and Production. 42, 1299–1310.
56. Stanley, T. A., Cochran, R.C., Vanzat, E.S., Harmon, D., and Corah, L. 1992. Periparturient changes in intake, ruminal capacity, and digestive characteristics in beef cows consuming alfalfa hay. Journal of Animal Science, 71, 788-795.
57. Strauch, T.A., Scholljegerdes, E.J., Patterson, D.J., Smith, M.F., Lucy, M.C., Lamberson, W.R., and Williams, J.E. 2001. Influence of undegraded intake protein on reproductive performance of primiparous beef heifers maintained on stockpiled fescue pasture. Journal of Animal Science. 79(3), 574-81. doi: 10.2527/2001.793574x. PMID: 11263816.
58. Summers, A.F., Meyer, T.L., and Funston, R.N. 2015. Impact of supplemental protein source offered to primiparous heifers during gestation on I. Average daily gain, feed intake, calf birth body weight, and rebreeding in pregnant beef heifers. Journal of Animal Science. 93(4), 1865-70. doi: 10.2527/jas.2014-8296. PMID: 26020208.
59. Titgemeyer, E.C., Armendariz, C.K., Bindel, D.J., Greenwood, R.H., amd Löest, C.A. 2001. Evaluation of titanium dioxide as a digestibility marker for cattle. Journal of Animal Science. 79, 1059–1063.
60. Valadares Filho, S.C., Silva, L.F.C., Gionbelli, M.P., Rotta, P.P., Marcondes, M.I., Chizzotti, M.L., Prados, L.F. 2016. Exigências Nutricionais de Zebuínos Puros e Cruzados - BRCORTE. 3a edição. Editora Federal de Viçosa, Viçosa-MG.

61. Valente, T.N.P., Detmann, E., de Queiroz, A.C., Valadares Filho, S.C., Gomes, D.I. and Figueiras, J.F., 2011. Evaluation of ruminal degradation profiles of forages using bags made from different textiles Revista Brasileira de Zootecnia, 40, 2565–2573
62. Van Soest, P. J. Nutritional Ecology of the Ruminant. 2nd. Ithaca, NY, USA: Comstock Publishing Associates, 1994. 476.
63. Vedovatto, M., Lecciolli, R.B., Lima, E.A., Rocha, R.F.A.T., Coelho, R.N., Moriel, P., Silva, L.G., Ferreira, L.C.L., Silva, A.F., Reis, W.V.A., Oliveira, D.M., and Franco, G.L. 2022. Impacts of body condition score at beginning of fixed-timed AI protocol and subsequent energy balance on ovarian structures, estrus expression, pregnancy rate and embryo size of Bos indicus beef cows. Livestock Science, 256, doi.org/10.1016.
64. Weston, R. (1982). Animal factors affecting feed intake. In J. B. Hacker (Ed.), Nutritional limits to animal production from pastures (p. 183-198). Queensland, St. Lucia: Commonwealth Agricultural Bureaux.
65. Wood, K.M, Awda, B.J., Fitzsimmons C., Miller, S.P., McBride, B.W., and Swanson, K.C. 2013. 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, 91, 5775-5784.

Figures

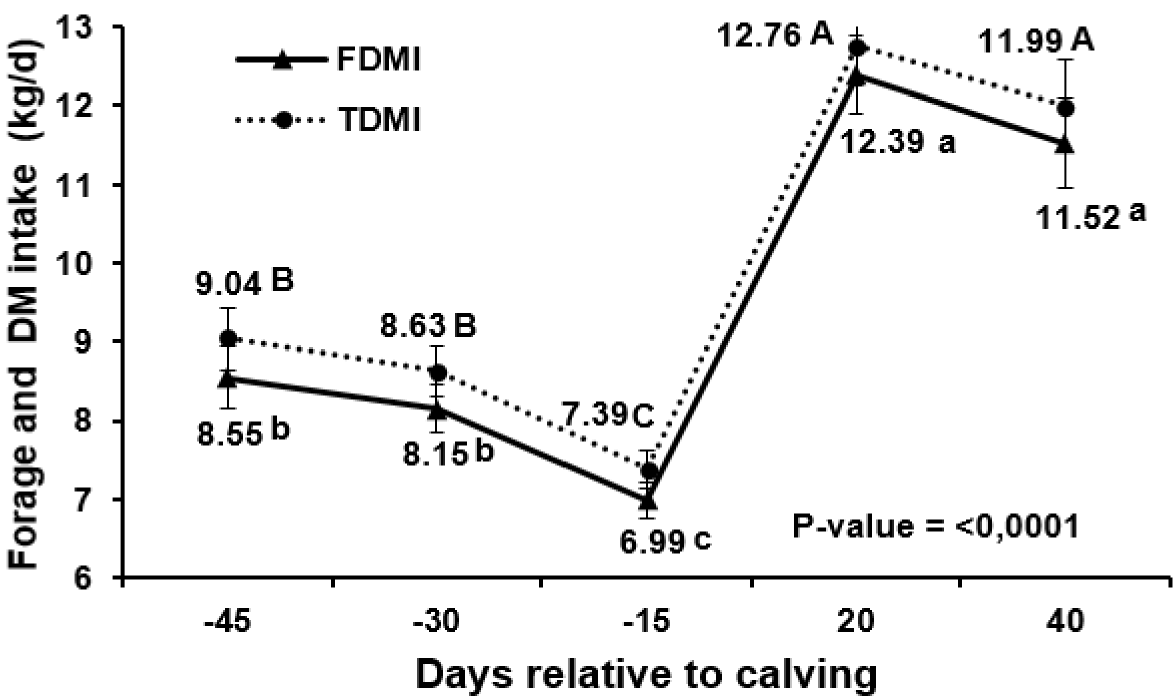

Figure 1

Total dry matter (DM intake) and forage intakes during the peripartum period of grazing Nellore cows. Means followed by different lowercase letters ($P \leq 0.0001$) among periods for the forage intake are different. Means followed by different capital letters ($P \leq 0.0001$) among periods for the DM intake are different.

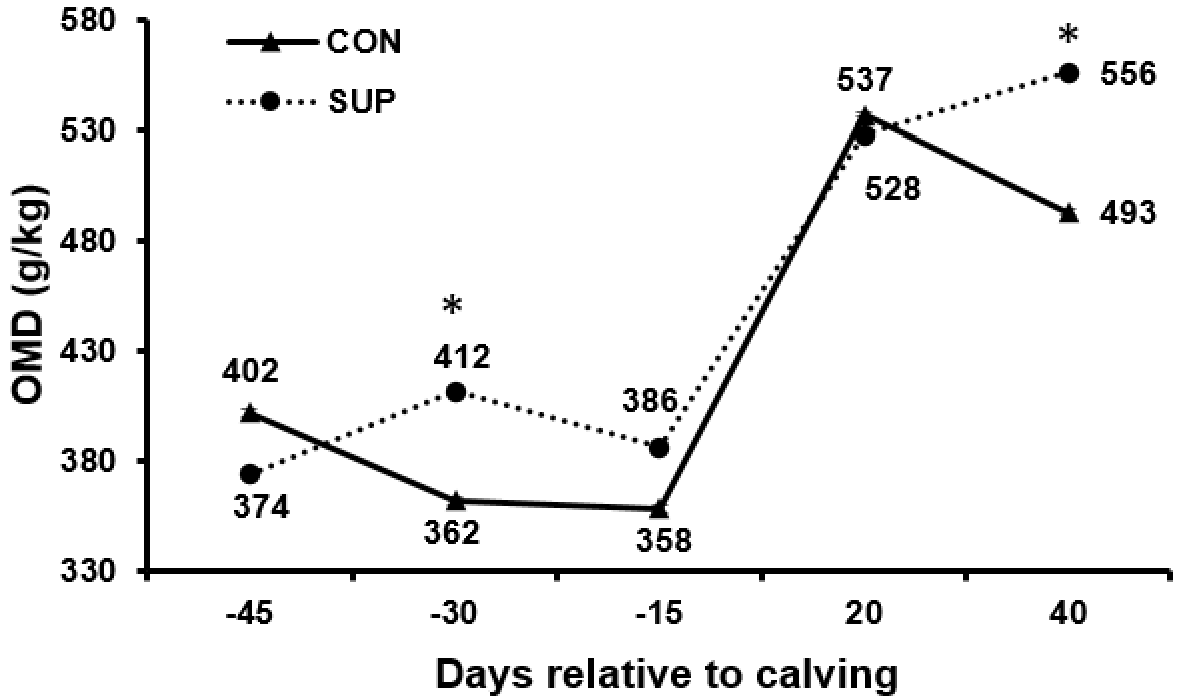

Figure 2

Apparent digestibility of organic matter (OMD) throughout the peripartum period of grazing Nellore cows. The averages of treatments (CON and SUP) within each period accompanied by (*) are different from each other ($P < 0.10$).

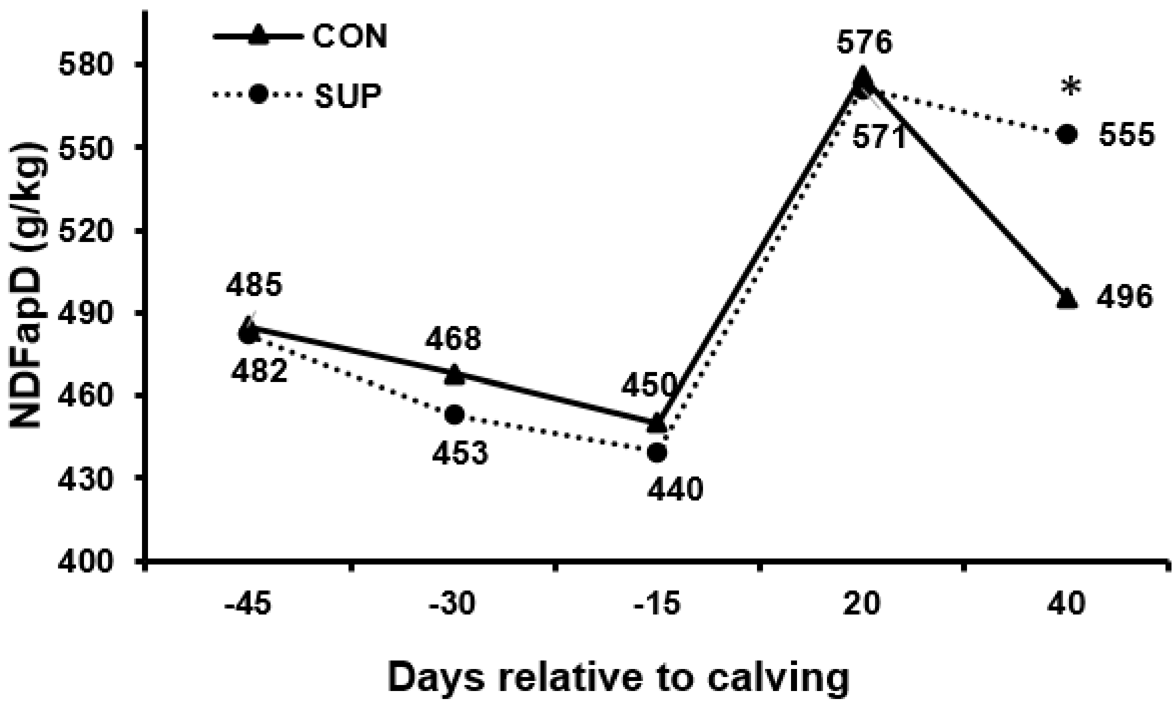

Figure 3

Apparent digestibility of neutral detergent fiber corrected for ash and protein (NDFapD) throughout the peripartum of grazing Nellore cows. The treatment means (CON and SUP) within each period accompanied by (*) are different from each other ($P \leq 0.10$).

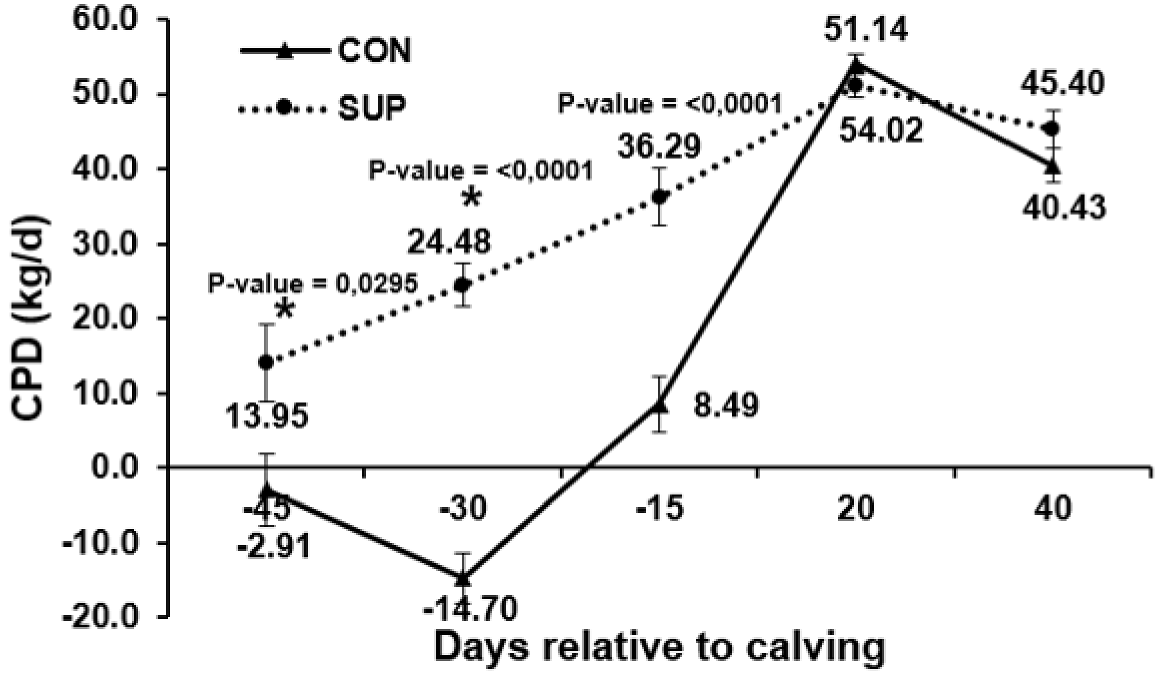

Figure 4

Apparent digestibility of crude protein (CPD) throughout the peripartum period of grazing Nellore cows. The treatment means (CON and SUP) within each period accompanied by (*) are different from each other ($P \leq 0.10$).

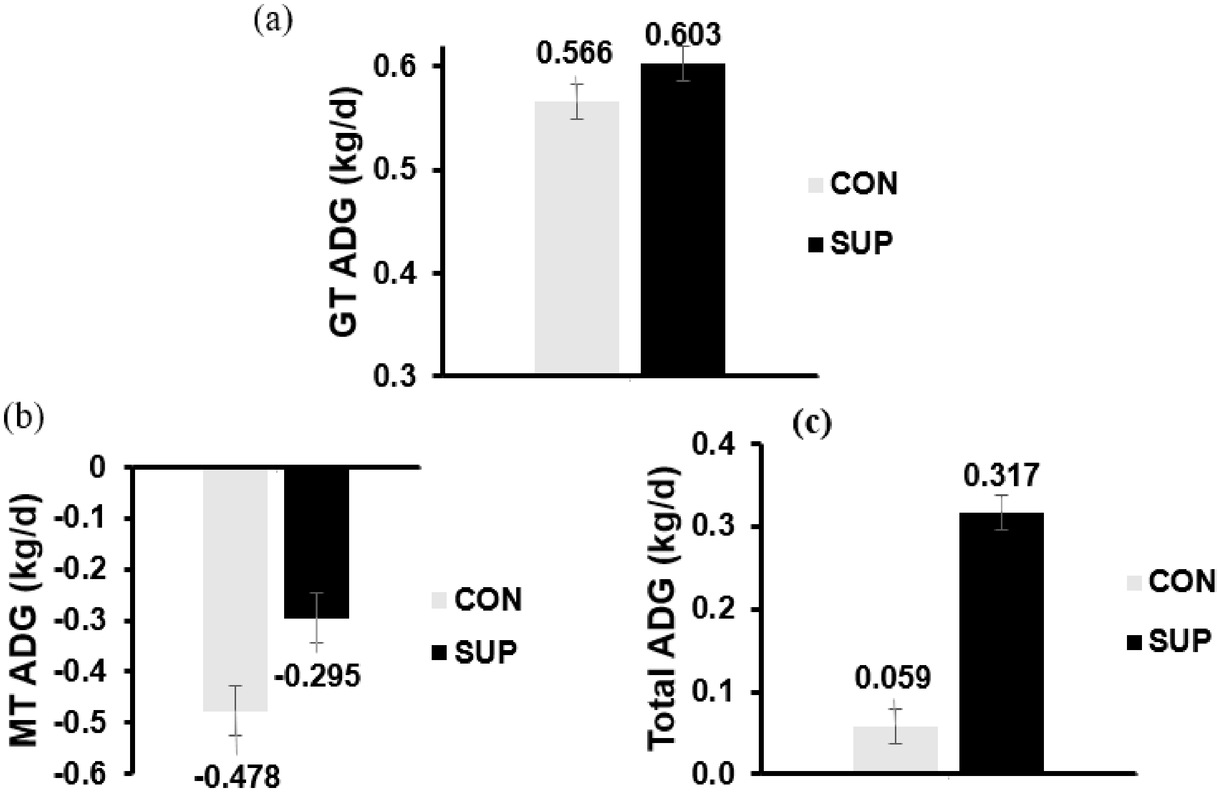

Figure 5

Gestational tissues ADG (a), maternal tissues ADG (b) and total ADG (c) during prepartum phase of the Nellore cows under grazing receiving or not protein supplementation. **P-value total ADG = 0.0017; P-value TG ADG = 0,1399 e P-value TM ADG = 0,0115.**